959 Issued July 6, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 181.

A. C. TRUE, Director.

MECHANICAL TESTS OF PUMPING PLANTS IN CALIFORNIA.

BY

J. N. Le CONTE and C. E. TAIT.

(Work done in cooperation between the Irrigation and Drainage Investigations of the Office of Experiment Stations and the State of California.)

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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LIST OF PUBLICATIONS OF THE OFFICE OF EXPERIMENT STATIONS ON IRRIGATION AND DRAINAGE.

NOTE.—Publications marked with an asterisk (*) are not available for distribution.

*Bul. 36. Notes on Irrigation in Connecticut and New Jersey. By C. S. Phelps and E. B. Voorhees. Pp. 64.

*Bul. 58. Water Rights on the Missouri River and its Tributaries. By Elwood Mead. Pp. 80.

Bul. 60. Abstract of Laws for Acquiring Titles to Water from the Missouri River and its Tributaries, with the Legal Forms in Use. Compiled by Elwood Mead. Pp. 77.

Bul. 70. Water-right Problems of Bear River. By Clarence T. Johnston and Joseph A. Breckons. Pp. 40.

*Bul. 73. Irrigation in the Rocky Mountain States. By J. C. Ulrich. Pp. 64.

*Bul. 81. The Use of Water in Irrigation in Wyoming. By B. C. Buffum. Pp. 56.

*Bul. 86. The Use of Water in Irrigation. Report of investigations made in 1899, under the supervision of Elwood Mead, expert in charge, and C. T. Johnston, assistant. Pp. 253.

*Bul. 87. Irrigation in New Jersey. By Edward B. Voorhees. Pp. 40.

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Bul. 96. Irrigation Laws of the Northwest Territories of Canada and of Wyoming, with Discussions by J. S. Dennis, Fred Bond, and J. M. Wilson. Pp. 90.

Bul. 100. Report of Irrigation Investigations in California, under the direction of Elwood Mead, assisted by William E. Smythe, Marsden Manson, J. M. Wilson, Charles D. Marx, Frank Soulé, C. E. Grunsky, Edward M. Boggs, and James D. Schuyler. Pp. 411.

*Bul. 104. The Use of Water in Irrigation. Report of investigations made in 1900, under the supervision of Elwood Mead, expert in charge, and C. T. Johnston, assistant. Pp. 334. (Separates only.)

*Bul. 105. Irrigation in the United States. Testimony of Elwood Mead, irrigation expert in charge, before the United States Industrial Commission, June 11 and 12, 1901. Pp. 47.

*Bul. 108. Irrigation Practice among Fruit Growers on the Pacific Coast. By E. J. Wickson. Pp. 54.

Bul. 113. Irrigation of Rice in the United States. By Frank Bond and George H. Keeney. Pp. 77.

Bul. 118. Irrigation from Big Thompson River. By John E. Field. Pp. 75.

*Bul. 119. Report of Irrigation Investigations for 1901, under the direction of Elwood Mead, chief. Pp. 401. (Separates only.)

Bul. 124. Report of Irrigation Investigations in Utah, under the direction of Elwood Mead, chief, assisted by R. P. Teele, A. P. Stover, A. F. Doremus, J. D. Stannard, Frank Adams, and G. L. Swendsen. Pp. 336.

Bul. 130. Egyptian Irrigation. By Clarence T. Johnston. Pp. 100.

Bul. 131. Plans of Structures in use on Irrigation Canals in the United States, from drawings exhibited by the Office of Experiment Stations at Paris, in 1900, and at Buffalo, in 1901, prepared under the direction of Elwood Mead, chief. Pp. 51.

*Bul. 133. Report of Irrigation Investigations for 1902, under the direction of Elwood Mead, chief. Pp. 266.

Bul. 134. Storage of Water on Cache la Poudre and Big Thompson Rivers. By C. E. Tait. Pp. 100.

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THE OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., December 17, 1906.

Sir: I have the honor to transmit herewith the report containing the results of mechanical tests of pumping plants in use in southern California in raising water for irrigation, prepared under the direction of Elwood Mead, chief of Irrigation and Drainage Investigations, by Prof. J. N. Le Conte and C. E. Tait. This is a continuation of the results published by this Office last year (Office of Experiment Stations Bul. 158). While the tests were planned and carried out by Professor Le Conte and Mr. Tait, all of the tables have been checked and much of the analysis and discussion written by S. M. Woodward of this Office. Its publication as a bulletin of this Office is recommended.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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ILLUSTRATIONS.

MECHANICAL TESTS OF PUMPS AND PUMPING PLANTS IN CALIFORNIA IN 1905.

INTRODUCTION.

During the summer of 1905, the Irrigation and Drainage Investigations of this Office continued the work begun during the previous year[a] of testing pumps and pumping plants with the object of determining the actual cost of pumping water for irrigation under various conditions and by various methods, and also the directions in which improvements may be sought for the purpose of decreasing the cost of pumping. The field work was conducted in the regions immediately surrounding Pomona and Riverside, in southern California, and on the lower Sacramento River in central California, among the reclamation districts.

The field work included two classes of tests. The first class consisted of complete tests, or those as nearly complete as the conditions of operation would permit. These required measurement of the power developed, either by means of the engine indicator or by indicating wattmeters, a continuous record of the lift, a measurement of the water by means of a weir, and a measurement of the fuel consumed. The second class consisted of partial tests, where no measurement of power was attempted, but merely a measurement of fuel (or electrical energy), water, and lift, for the purpose of determining the cost of pumping water. Throughout the season's work particular efforts were made to obtain the cost of installation and operation, in order to estimate the fixed charges and labor items which constitute so large a portion of running expenses.

The field work has been sufficient for the working out of a fairly convenient and satisfactory system of testing, and for the benefit of others who wish to make similar tests the methods used are given below.

MEASUREMENT OF FUEL.

Gasoline for small engines is usually contained in cylindrical tanks at some distance from the pump house and piped to the engine. In such cases the position of the surface of the oil is taken with a small

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 158.

hook gauge, consisting of a sharpened piece of wire bent into the form of a hook and fastened to the end of a stick. The surface is noted at the beginning and end of the test by marks made on the stick with the blade of a penknife. The distance between these marks should be measured with a fine scale, and from this and the dimensions of the tank the volume of the gasoline is computed. It is of particular importance to make this measurement every hour in order that an accidental change in the running conditions, or an error, shall not destroy an otherwise good test. When the tank is irregular in cross section, or when though cylindrical the axis is horizontal, the surface is noted at the beginning of the test as before, and at the end of the test the engine is shut down at once. Weighed quantities of gasoline are then poured into the tank until the level returns to the original mark, and the total weight consumed is known. A tested spring balance weighing up to 20 pounds is convenient for this work. Crude oil used for steam boilers can be measured in the same way unless the area of the containing tank is too great to make an appreciable fall in the surface during the test. In this case (and in fact in all cases where possible) the oil should be weighed out. The pipe leading from the tank to the boiler should be cut, and the burners made to draw their supply from a barrel on the floor of the station. This in turn is replenished from time to time from a second barrel on a platform scale. This second barrel is filled either directly by gravity from the oil tank or by a hand pump from the same source of supply. In this way weighed quantities of oil can be poured into the first barrel, but care should be taken that the level of the oil in this latter is the same at the beginning and end of the test. In all cases the density of the gasoline, or oil, should be taken on a hydrometer so that weight can be reduced to gallons.

MEASUREMENT OF POWER.

Measurement of the indicated horsepower of a gas engine is the most difficult of all measurements to make in the field. It was found in our experience that all ready-made reducing motions, or reducing wheels, are unsatisfactory when used on the ordinary gas engine, and that the pendulum-reducing motion gives the best results. The following is a description of the device used: In nearly all gas engines there will be found a set screw at A (fig. 1) which serves to hold the wrist pin in the piston and prevent it from turning. In many engines there are two of these. This set screw is removed and another inserted which has a slotted head, as at A (fig. 2). Several of these should be kept on hand to correspond with the standard sizes of set screws—that is one-half inch, five-eighths inch, three-fourths inch, etc. This slotted set screw is set into the piston with the slot vertical. A number of flat links are then made with lengths

varying from 14 to 28 inches and about three-sixteenths by three-fourths inch in cross section. The longer ones may be made heavier, say one-fourth by 1 inch, but the ends must be brought down to three-sixteenths inch in thickness to fit the slots in the set screws. The link is chosen which corresponds to the stroke of the particular engine under test, and one end is fastened into the slotted set screw by a three-sixteenths inch split pin. A lever or pendulum is then constructed of light strong wood, as shown in figure 2. The lower end is protected with one-eighth inch iron plate, as shown, so as to receive the other end B of the link, and this latter is secured thereto

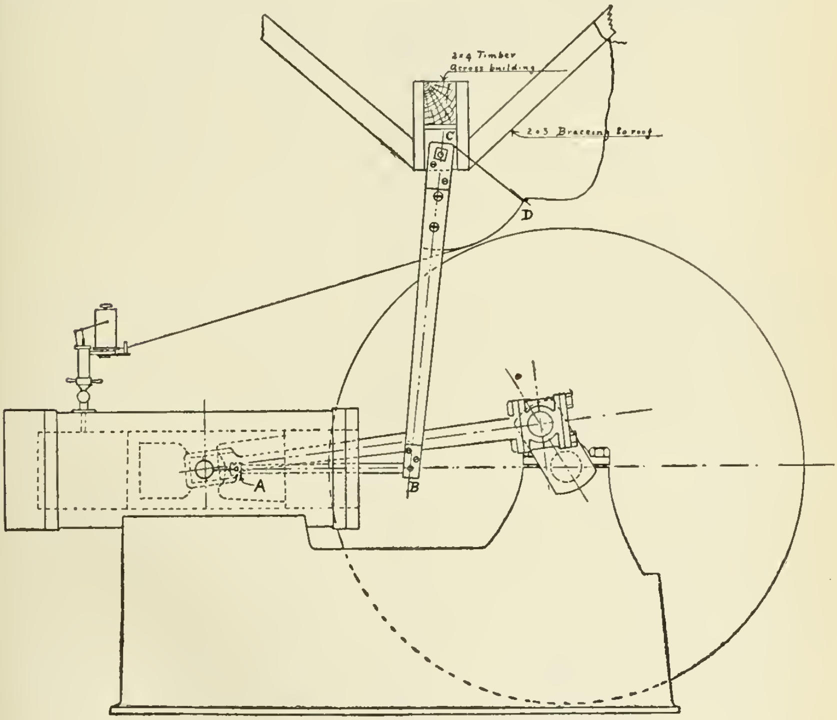

FIG. 1. Apparatus for testing gasoline engines.

with a small bolt. At the upper end of the pendulum there is fastened by a couple of wood screws a sector, whose radius corresponds to the stroke of the engine under test, and both sides are protected with one-eighth inch iron plate. The whole is hung from an iron pin containing a shoulder, as shown at C (fig. 2). A couple of jam nuts prevent the pendulum from slipping off the pin, which is passed through a wooden block nailed to a timber which spans the pump house above the engine at right angles to the line of connection. This timber should be braced from the roof or sides of the building. The pendulum is so adjusted that it hangs vertical with the piston at mid stroke and with the link AB horizontal. A groove is cut

on the perimeter of the circular sector, and a piece of metal with a V-shaped notch at D (fig. 2) engages a knot on the indicator card, so that the indicator can be hooked up or unhooked without difficulty. Care should be taken that the whole apparatus is well constructed, so that no breakdown may occur when running at high speed. Where engines are "short connected" no great error is caused by allowing the end B of the pendulum to override the crank at its extreme outward throw. Of course only such engines

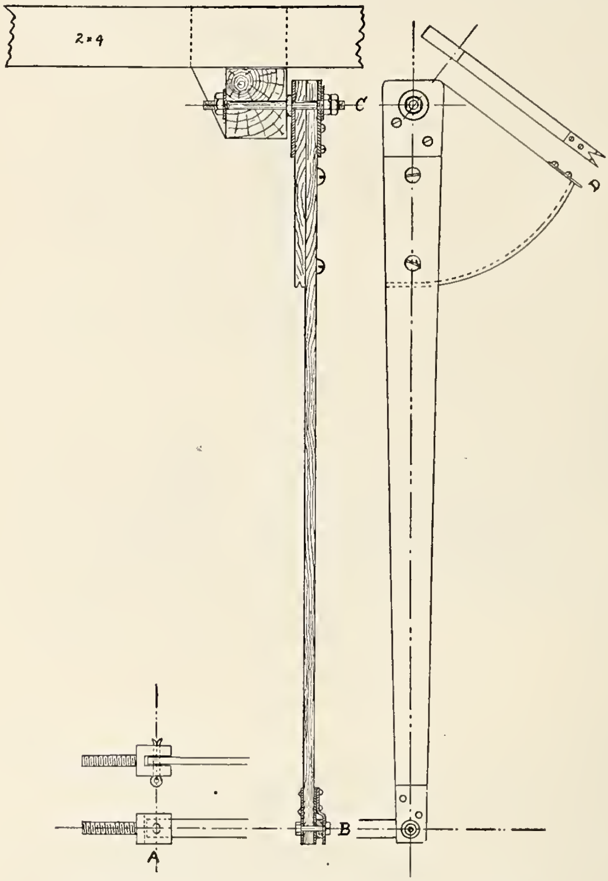

Fig. 2.—Detail of apparatus for testing gasoline engines.

can be indicated as have the necessary opening for the indicator plug or some opening into the explosion chamber to which the indicator can be attached by short piping. Nearly all steam engines are already piped for the indicator and with them the ordinary reducing wheel may be used.

In taking cards on a gasoline engine it has been our custom to take a number on the same sheet, say six to ten. Successive cycles in such engines are seldom identical, so that a series of cycles is

necessary to get an average indicated horsepower. Where the cycles are very nearly alike, so that the lines run close together and blur into one another, the planimeter can be run by eye through the mean position of such lines. Where the cycles differ widely the planimeter can be run around each separately and the set averaged in this way. A single cycle taken with the indicator on a gasoline engine is of little use in computing horsepower. The indicated horsepower is computed by the ordinary formula:

$$\text{Indicated horsepower} = \frac{PLAN}{33,000},$$

in which, P = mean effective pressure in pounds per square inch.
L = length of stroke in feet.
A = effective area of piston in square inches.
N = number of effective strokes per minute.

For measuring electric power the indicating wattmeter is used. Electrical horsepower is computed by dividing the number of kilowatts by 0.746.

MEASUREMENT OF LIFT.

Few pumps are so arranged that it is convenient to attach pressure and vacuum gauges and thus obtain the actual head worked against by the pump. In deep-well pumps, air lifts, and centrifugals running under water it is practically impossible to use gauges, and so few plants were found where gauges could be properly applied that the attempt to get the working head by this method was abandoned and the measured or leveled head was used instead. This is obtained by measuring with a tape the vertical distance from the surface of the water in the sump or in the well casing to the center of the final discharge. When the pump runs under water in an open pit or when the suction draws from a ditch or stream, this is most easily done by attaching a float to the end of the tape and lowering it until it touches the water. When the level of the water falls so as to be below the top of the casing of a bored well or in an air well, the measurement is more difficult. Where there is sufficient space between the well casing and the suction pipe, say an inch and a half, a small float may be lowered to the water level if the well is bored straight. A long rubber tube, open at both ends, is sometimes used for determining water levels in wells. By weighting one end the tube can be lowered into a very narrow space and the water level can be determined by blowing through the tube with a steady pressure. However, the crookedness of the well casing and the sleeves on the suction pipe may prevent the lowering of the tube. A dry steel tape may be lowered into the well and withdrawn, the wet portion indicating the water level. The difficulty here is that the wet sides of the well casing and suction pipe may give false indications, and it entirely fails

if water is draining from the pit into the well. With all the different methods tried, several instances were found where it was impossible to measure with certainty the depth to water. Since the actual head pumped against is valuable information for the irrigator himself, the writer proposes the following arrangement, which, if installed when the plant is erected, would furnish an easy and certain method of determining the lift: When the pump or suction pipe is first lowered into the well, let a small pipe, of, say, three-eighths or one-half inch in diameter, be lowered with it. This can be secured to the sides of the suction pipe at intervals and should reach within a foot or so of its lower end. Its length must be carefully measured before lowering. The upper end should be connected to a receiver of about a cubic foot capacity and an accurate pressure gauge attached to this latter. Air can be forced into this receiver with a small bicycle pump, or if the engine be so arranged as to start by compressed air this can be used to charge the receiver. The pressure gauge will then rise till the air bubbles out of the end of the small pipe, but no higher. The supply of compressed air being discontinued, the reading of the gauge, multiplied by 2.3, will give the length of the small pipe submerged, which when subtracted from the total length of the small pipe will give the depth to water. It is evident that a paper dial, graduated so as to read the actual lift on the pump directly, could be substituted for the regular one on the gauge.

MEASUREMENT OF WATER.

The discharge was measured in nearly every instance by means of a weir. Many plants in southern California have weirs installed either at the pump house or somewhere on the pipe line. These usually consist of a concrete box, which receives the water from the pump at one end and delivers the water over a weir set in a concrete partition into a second compartment, from which the pipe line distributes the water to the orchard. When the pipe line is very long or of too small diameter or has little slope, the weir is drowned and rendered useless. The free contractions of most weirs made in this way are interfered with by the concrete of the partition coming too close to the crest and sides of the weir. The box is nearly always too short to permit the use of baffle plates to still the violent commotion produced by the pump discharge. For purposes of testing, an ordinary weir board set in an open ditch is vastly better than the majority of permanent weirs found in the ditches tested.

All the results of these measurements have been computed by means of the Francis weir formula,[a] that being the basis of most of the weir tables in use by the irrigators and also the one employed

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[a] $Q=3.33\ (b-.2h)h^{3/2}$.

by this Office in compiling its weir tables.[a] The writer is certain, however, from his own experiments, as well as from the work of others, that this formula gives results too small for low heads and narrow crests. Francis himself did not intend it to be used for heads under 6 inches and for breadths under 3 feet, yet it has been extended to cover all cases of heads and breadths without regard to the truth. A closer approximation to the discharge would probably be reached by using the weir coefficients of Hamilton Smith, jr.[b] The same criticism applies to the Cipolletti weir formula as generally used.

The head on the weir has been measured by an ordinary rule held on the head of a nail, which was previously leveled with the crest of the weir by means of a straightedge and machinist's level. The readings could not be made closer than the nearest one-sixteenth inch. It was on account of this rather rough method of measurement that no closer approximation than the Francis formula was made.

The useful water horsepower of a pump is computed by the following formula: Useful water horsepower $= \frac{Q\ w\ h}{550}$, in which

Q = volume of water pumped in cubic feet per second.

w = weight of 1 cubic foot of water = 62.3 pounds.

h = lift or head through which the water is actually raised, in feet.

MEASUREMENT OF FEED WATER.

Feed water was measured wherever possible, by taking the fall in the level of the feed tank, and in one instance with a Worthington piston meter, already installed in the feed line. For a careful test the water should be weighed out on a platform scale exactly as described for oil measurements. As the amount of feed water handled, however, is more than ten times that of the oil, the apparatus required must be many times larger and more elaborate. Such a method is scarcely applicable to tests of the character of those herein described, especially as the feed water is the least important factor from our point of view.

COMPLETE FIELD TESTS.

A description of each of the thirty-eight complete tests is given below. This description includes the name of the owner of the plant and its location, a description of the equipment of the plant, a complete log of test, and such explanations of the details of the test as are necessary for its complete understanding. Following these details the results of the tests are summarized in several tables and a discussion is given of the results. The summary tables contain

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 86.

[b] Hydraulics by Hamilton Smith, jr. John Wiley, N. Y.

considerable original data on costs not given with the descriptions of the separate tests.

Tests numbered 1 to 11 are of plants run by gasoline engines; 12 to 24 are of plants run by electric motors, and 25 to 38 are of plants run by steam.

PLANTS DRIVEN BY GASOLINE ENGINES.

In obtaining indicator cards on all the gasoline engines a tested 205-pound spring was used in the indicator.

TEST NO. 1.—PLANT OWNED BY D. W. HELM, NEAR POMONA.

Equipment.—An 11-horsepower, White & Middleton gasoline engine; cylinder 6 by 12 inches; speed, 240 revolutions per minute; pulley, 36 by 10 inches; a No. 4 single vertical Byron Jackson centrifugal pump; one 4-inch suction pipe from a 7-inch well 286 feet deep; discharge pipe 4-inch O. D. screwed casing; depth of pit about 48 feet; two pulleys 10 by 10 inches (tight and loose for starting); a $7\frac{1}{2}$-inch canvas belt, with tightening pulley, direct quarter-turn on 18-foot centers; a 15-inch rectangular weir, put in by testing party, but with weir box much too small.

No suction lift (pump just level with water); discharge lift, 44.4 feet.

This plant belongs to the poorer class. The engine is old and badly abused. The pump, which is under water when not in use, draws air either into the suction pipe or through a faulty joint as soon as the pit is cleared of water. The owner, therefore, has been accustomed to run the engine below full speed, so as to keep the level of the water in the pit even with the pump. The writer is of the opinion that the trouble here is the same as in the case of test No. 5 (p. 20), where air bubbles in suspension in the water are drawn by the rush of water between the well casing and the suction pipe, causing the pump to lose its priming. As soon as the pumping ceases, the well, pit, and pump fill again, and the process is repeated. When run up to full speed this intermittent action occurs. When run below speed it is possible to maintain a constant flow. The test was made under these latter conditions.

Fuel.—No. 2 engine distillate, 48° Baumé, costing $5\frac{1}{2}$ cents per gallon delivered.

Log of test No. 1, D. W. Helm, May 31, 1905.

No.	Time.	Revolutions per minute. Engine.	Revolutions per minute. Pump.	Explosions per minute.	Indicator card. Area.	Indicator card. Length.	Mean effective pressure per square inch.	Indicated horsepower.	Discharge per second.	Measured head.	Useful water horsepower.
					Sq. in.	*Inches.*	*Pounds*		*Cu. ft.*	*Feet.*	
1	10.22	230	800	105	1.52	3.45	90.3	8.12		44.0	1.63
2	10.26			108	1.51	3.46	89.5	8.28			
3	10.30	210	685	108	1.16	3.46	68.7	6.36		44.0	1.63
4	10.34	230		98	.91	3.42	54.6	4.58		45.0	1.67
5	10.38	214	720	98	.87	3.42	52.1	4.37		44.0	1.63
6	10.45			111	1.30	3.45	77.2	7.34			
7	10.47	200	690	99	.91	3.43	54.4	4.61		44.0	1.63
8	10.51			98	.90	3.43	53.8	4.52			
9	10.53	208	694	100	1.13	3.44	67.3	5.77		44.3	1.65
10	10.58			97	1.10	3.44	65.6	5.45			
11	11.03	206	690	99	1.14	3.44	67.9	5.76		44.3	1.65
12	11.09			96	.91	3.43	54.4	4.47			
13	11.14	206	700	103	1.00	3.44	59.6	5.26		45.0	1.67
14	11.23			99	.95	3.42	56.9	4.83			
15	11.32	200	695	98	.96	3.43	57.4	4.82		45.0	1.67
	Mean							5.64	0.328	44.4	1.65

Test No. 2.—Plant Owned by the Sam Lee Company, near Pomona.

Equipment.—A 12-horsepower Fairbanks-Morse gasoline engine; cylinder, $8\frac{5}{16}$ by 14 inches; pulley, 35 inches; engine old and in poor condition; a No. 4 vertical single Byron-Jackson centrifugal pump, one 4-inch suction pipe from 10-inch well 200 feet deep; diameter of discharge pipe, 6 inches; pulley, 10 inches; $7\frac{1}{2}$-inch canvas belt, 20 feet between centers, direct quarter-turn; an 18-inch Cipolletti weir installed by testing party.

Suction lift, 20.5 feet; discharge lift, 41.4 feet; total lift, 61.9 feet.

The engine in this case was old, much worn, and badly abused, but the pump was new, having been in but three months. Later in the season the engine was replaced by an electric motor, and a test under the latter conditions made an interesting comparison with the present one. (See test No. 12.)

Fuel.—No. 2 engine distillate, 44° Baumé; density, 0.811, costing $5\frac{1}{2}$ cents per gallon.

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Log of test No. 2, Sam Lee Company, September 5, 1905.

No.	Time.	Revolutions per minute.		Explosions per minute.	Indicator card.		Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Engine.	Pump.		Area.	Length.						
					Sq. in.	*Inches.*	*Pounds*		*Inches.*	*Cu. ft.*	*Feet.*	
1	10.30........	282	960	97	1.03	2.36	89.5	16.6	3⅛	0.671	......	......
2	10.45........	281	955	97	.97	2.35	84.6	15.7	3⅛	.671	......	......
3	11.00........	280	954	96	.99	2.33	87.1	16.0	3⅛	.671	......	......
4	11.15........	280	957	96	.99	2.34	86.7	16.0	3⅛	.671	......	......
5	11.30........	279	955	97	1.00	2.34	87.6	16.3	3⅛	.671	......	......
6	11.45........	280	955	98	1.00	2.35	87.2	16.4	3⅛	.671	......	......
7	12.00........	279	956	98	1.03	2.35	89.8	16.9	3⅛	.671	......	......
8	12.15........	279	955	98	1.00	2.37	86.5	16.3	3⅛	.671	......	......
9	12.30........	280	956	98	1.02	2.34	89.4	16.8	3⅛	.671	......	......
	Mean...	....	....	......	....	....	....	16.3	....	.671	61.9	4.70

Test No. 3.—River Station No. 1 of the Riverside Water Company, near Colton.

Equipment.—A 50-horsepower Fairbanks-Morse gasoline engine; cylinder, 16 by 18 inches; speed about 180 revolutions per minute; pulley, 72 by 12 inches; a No. 10 vertical single Byron Jackson centrifugal pump; one 10-inch suction pipe 30 feet long from well directly below pump, and one 7-inch suction pipe from another well 200 feet away; discharge pipe, 19 inches; an 11-inch rubber belt with quarter-turn; a 48-inch contracted rectangular weir already in place.

No suction lift (pump under water); discharge lift, 11.31 feet (measured).

This plant was running on Coalinga distillate, the oil being fed through the ordinary form of retort, heated by the exhaust gases. The engine is started on No. 1 distillate, and when the retort is thoroughly heated the Coalinga is turned in. The engine was in bad shape at the time of the test, the piston being worn. It was considerably too large for its work, as can be seen by comparing the explosions per minute (50) with the revolutions per minute (180). No examination could be made of the pump, which was under water.

Fuel.—Coalinga distillate, 35° Baumé, costing 5 cents per gallon.

This plant gave the lowest efficiency of all the gasoline plants tested. How much of the trouble was due to the engine and how much to the pump could only be ascertained by a brake test.

It is understood from the owners of the plant that it was working under very unfavorable conditions at the time this test was made, and that later in the season, when the water plane is lowered and when the head is therefore largely increased, the efficiency is much higher.

Log of test No. 3, River station No. 1, June 22, 1905.

No.	Time.	Revolutions per minute (engine).	Explosions per minute.	Indicator card. Area	Length.	Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
				Sq. in.	*Inches.*	*Pounds.*		*Inches.*	*Cu. ft.*	*Feet.*	
1	3.15	182	......	......	......	......	......	$7\frac{3}{32}$	5.87	11.2	......
2	3.30	182	51.5	1.15	2.89	81.6	38.4	$7\frac{3}{16}$	5.99	10.6	......
3	4.00	182	51.5	1.15	2.90	81.3	38.3	$7\frac{5}{32}$	5.95	11.2	......
4	4.30	182	50.0	1.18	2.90	83.4	38.1	$7\frac{1}{8}$	5.91	......	......
5	5.00	183	50.0	1.17	2.90	82.7	37.8	$7\frac{5}{32}$	5.95	11.7	......
6	5.30	182	50.5	1.18	2.90	83.4	38.5	$7\frac{5}{32}$	5.95	......	......
7	6.00	182	50.0	1.15	2.90	81.3	37.2	$7\frac{5}{32}$	5.95	11.9	......
8	6.30	182	50.0	1.16	2.90	82.0	37.5	......	......	......	......
	Mean	......	......	......	......	......	38.0	......	5.94	11.3	7.60

TEST NO. 4. PLANT OWNED BY THE KINGSLEY TRACT WATER COMPANY, BETWEEN POMONA AND CLAREMONT.

Equipment.—A 32-horsepower Fairbanks-Morse gasoline engine; cylinder, 11.5 by 18 inches; speed about 200 revolutions per minute; pulley, 60 by 13 inches; a No. 4 compound vertical Byron Jackson centrifugal pump; one 5-inch suction pipe in a 7-inch well; discharge pipe, 6-inch O. D. casing; the pit is about 87 feet deep; pulley, 13 by 18 inches; pump under water before starting; a 10-inch quarter-turn canvas belt with tightening pulley, 28 feet between centers; a 16-inch rectangular contracted weir, already in place.

Suction lift, 8.3 feet (estimated); discharge lift, 88.3 feet (measured); total lift, 96.6 feet.

This test was not altogether satisfactory. In the first place, it was not possible to measure directly the suction lift, owing to the small space between the well and suction pipe, which was interrupted by sleeves. It had to be estimated in the following manner: The reading of the vacuum gauge was noted at the instant the level of the water fell to the level of the pump; this reading, subtracted from subsequent readings of the gauge, gave a fair measure of the suction lift. It is believed that the results do not differ from the true value by more than a foot or two. The second difficulty lay in the fact that the large cement pipe used in conveying the water to the weir box would not carry all of the discharge. A small amount overflowed the standpipe, and this was estimated, as well as possible, at about 63 gallons per minute.

Fuel.—No. 2 engine distillate, 48° Baumé; density, 0.794, costing 6 cents per gallon.

Log of test No. 4, Kingsley Tract Water Company, June 1, 1905.

No.	Time.	Revolutions per minute.		Explosions per minute.	Indicator card.		Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Engine.	Pump.		Area.	Length.						
					Sq. in.	*Inches.*	*Lbs.*		*Ins.*	*Cu. ft.*	*Feet.*	
1	1.45	190	880	83	1.49	4.36	70.1	27.5	......	......	81.0	......
2	2.15	192	870	83	1.47	4.39	68.6	26.9	......	......	84.0	......
3	2.30	191	866	84	1.48	4.39	69.1	27.4	......	......	94.8	......
4	2.45	191	870	82	1.42	4.40	66.2	25.6	$3\frac{5}{8}$	0.844	95.9	9.17
5	3.00	192	872	82	1.44	4.40	67.1	26.0	$3\frac{5}{8}$	.844	96.2	9.20
6	3.15	192	870	81	1.49	4.40	69.4	26.5	$3\frac{5}{8}$	.844	96.2	9.20
7	3.30	192	872	83	1.41	4.40	65.7	25.7	$3\frac{5}{8}$	.844	96.5	9.23
8	3.45	192	875	82	1.44	4.41	66.9	25.9	$3\frac{5}{8}$	.844	96.5	9.23
9	4.00	192	876	81	1.44	4.40	67.1	25.7	$3\frac{3}{8}$	.772	96.7	8.45
10	4.15	192	875	82	1.53	4.40	71.3	27.6	$3\frac{1}{2}$	.807	96.8	8.85
11	4.30	192	873	81	1.49	4.42	69.1	26.4	$3\frac{9}{16}$	.826	96.8	9.06
12	4.45	192	872	82	1.46	4.40	68.0	26.3	$3\frac{9}{16}$	.826	96.8	9.06
	Mean							26.5	......	.829	96.5	9.05

Test No. 5.—Plant Owned by Dr. George E. Mosher, Pomona.

Equipment.—A 30-horsepower West Coast gasoline engine; cylinder, $9\frac{1}{2}$ by 20 inches; speed, about 260 revolutions per minute; pulley, 48 by 10 inches; throttling governor. No. 6 single vertical Byron Jackson centrifugal pump; one suction pipe, 8 inches in diameter and 40 feet long; discharge pipe 10-inch riveted casing; pulley, 16 by 17 inches; direct, quarter-turn, 10-inch rubber belt, 28 feet between centers; a 24-inch rectangular contracted weir put in by testing party.

Suction lift, 18.6 feet (measured); discharge lift, 49.3 feet (measured); total lift, 67.9 feet.

This plant is of modern design, and would have given excellent results except for an unfortunate difficulty, one often met with in plants of this type, and one of the most troublesome to deal with. The well casing in this instance was perforated from the bottom of the pit to a considerable depth. A large part of the total flow of the well was taken from a stratum of gravel a few feet below the bottom of the pit, and from the drainage of the pit itself. As soon as the pump was started the level in the well fell at once to about 17 feet below the top of the casing. The large volume of water entering from the upper perforations and the pit, and falling through the space between the casing and the suction pipe, drew along with it a considerable volume of air, which was carried in the form of bubbles to the end of the suction pipe. Here the air entered the pump, partially destroying its priming, and caused the flow to fall so low as to check the travel of air down the well. The pump immediately picked up its water again and repeated the process. The result was a continual pulsation in the discharge. These causes were easily verified by fluctuation of over 6 feet in the water level of the well, by the regular

vibration of 5 or 6 inches in the vacuum gauge, and by the intermittent character of the discharge itself. The trouble is a peculiar one, and the writer has not been fortunate enough to see the following remedies actually tried, but they are given here merely as suggestions: To eliminate perforations in the casing down to at least 30 feet below the bottom of the pit; to remove the suction pipe and surround it with a number of flanges which just fit the casing; to calk the top of the well around the suction pipe. It is understood that increasing the length of the suction pipe does not remove the trouble, as air is carried down to almost any depth by this cause. Of course such action is fatal to high efficiency, as the results show.

Fuel.—No. 2 engine distillate, 48° Baumé; density, 0.794, costing $5\frac{1}{2}$ cents per gallon.

Log of test No. 5, Dr. George E. Mosher, June 8, 1905.

No.	Time.	Revolutions per minute. Engine.	Revolutions per minute. Pump.	Explosions per minute.	Indicator card. Area.	Indicator card. Length.	Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
					Sq. in.	Inches.	Lbs.		Ins.	Cu. ft.	Feet.	
1	2.30	276	783	138	1.23	3.40	74.2	36.6	$4\frac{3}{8}$	1.41	67.9	10.8
2	2.45	......	......	140	1.21	3.44	72.1	36.1	$4\frac{3}{8}$	1.41	......	10.8
3	3.00	277	792	140	1.21	3.42	72.5	36.3	$4\frac{5}{16}$	1.38	......	10.6
4	3.15	275	790	138	1.20	3.43	71.7	35.4	$4\frac{5}{16}$	1.38	......	10.6
5	3.30	267	760	134	1.21	3.40	73.0	35.0	$4\frac{1}{4}$	1.35	......	10.4
6	3.45	268	......	134	1.19	3.38	72.2	34.6	$4\frac{1}{4}$	1.35	67.9	10.4
7	4.00	265	766	133	1.17	3.37	71.2	33.9	$4\frac{3}{16}$	1.33	......	10.2
8	4.15	265	770	132	1.17	3.37	71.2	33.6	$4\frac{3}{16}$	1.33	......	10.2
9	4.30	266	770	133	1.19	3.38	72.2	34.4	$4\frac{3}{16}$	1.33	......	10.2
10	4.45	266	......	133	1.23	3.39	74.4	35.4	$4\frac{3}{16}$	1.33	67.9	10.2
11	5.00	270	779	135	1.21	3.37	73.6	35.6	$4\frac{3}{16}$	1.33	......	10.2
12	5.15	271	780	136	1.23	3.41	73.9	36.0	$4\frac{1}{4}$	1.35	......	10.4
13	5.30	270	782	135	1.18	3.40	71.1	34.4	$4\frac{1}{4}$	1.35	67.9	10.4
	Mean	......	......	......	......	......	......	35.2	......	1.36	67.9	10.4

Test No. 6.—Plant Owned by R. M. Thurman, near Pomona.

Equipment.—A 30-horsepower White & Middleton gasoline engine; cylinder, 10 by 18 inches; pulley, 54 inches; a No. 4 vertical Hunsaker centrifugal pump; one 6-inch suction pipe entering the bottom of the pump from a 10-inch well 385 feet deep; diameter of discharge pipe, 8 inches; pulley, 12 inches; 10-inch canvas belt, 30 feet between centers; a 24-inch contracted rectangular weir.

Suction lift, 21 feet (measured); discharge lift, 41 feet (measured); total, 62 feet.

In this plant the gasoline was measured by pouring a weighed quantity by hand into the engine cup, care being taken not to allow any overflow. In this way a test can be made in a much shorter time and more accurately than by noting the fall in the tank level.

Fuel.—No. 1 engine distillate, 45.5° Baumé, density 0.804, costing 6.75 cents per gallon.

Log of test No. 6, R. M. Thurman, September 27, 1905.

No.	Time.	Revolutions per minute.		Explosions per minute.	Indicator card.		Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Engine.	Pump.		Area.	Length.						
					Sq. in.	*Inches.*	*Lbs.*		*Ins.*	*Cu. ft.*	*Feet.*	
1	3.30	201	865	100	1.19	2.96	82.4	29.4	$4\frac{9}{16}$	1.50	......	......
2	3.40	204	880	102	1.18	2.96	81.7	29.8	$4\frac{9}{16}$	1.50	......	......
3	3.50	197	827	98	1.21	2.96	83.8	29.3	$4\frac{9}{16}$	1.50	......	......
4	4.00	210	915	105	1.07	2.95	74.4	27.9	$4\frac{5}{8}$	1.53	......	......
5	4.10	210	930	105	1.18	2.96	81.7	30.6	$4\frac{5}{8}$	1.53	......	......
6	4.20	205	890	102	1.16	2.95	80.6	29.3	$4\frac{9}{16}$	1.50	......	......
7	4.30	196	895	98	1.19	2.96	82.4	28.8	$4\frac{5}{8}$	1.53	......	......
	Mean	......	......	......	......	......	......	29.3	......	1.51	62.0	10.6
8	4.50	235	......	44	.61	2.96	42.2	6.6	Pump uncoupled from shafting.			
9	5.00	202	......	39	.99	2.94	69.0	9.6				
	Mean	......	......	......	......	......	......	8.1				
10	5.15	204	......	16	1.50	2.96	103.9	5.9	Belt thrown off entirely.			
11	5.25	204	......	13	1.56	2.96	108.0	5.0				
	Mean	......	......	......	......	......	......	5.4				

Test No. 7.—Plant Owned by Lee Matthews, near Pomona.

Equipment.—A 30-horsepower White & Middleton gasoline engine; cylinder, 10 by 18 inches; speed, about 185 revolutions per minute, exploding every charge; pulley, 42 by 12 inches; a No. 5 compound vertical Byron Jackson centrifugal pump; one 7-inch suction pipe from a 10-inch well; discharge pipe, 7-inch riveted casing, containing 1 check valve; pulley, 11.5 by 17 inches; a 10-inch canvas, direct, quarter-turn belt, with tightening pulleys, 27.6 feet between centers; a 24-inch rectangular contracted weir put in by the testing party over the old weir.

Suction, 20.5 feet (estimated); discharge lift, 73 feet (measured); total lift, 93.5 feet.

The suction lift could not be measured for the same reasons as in test No. 3, and had to be estimated by the vacuum gauge in the same manner. This is one of the best gasoline plants tested by our party. The machinery is kept clean and in perfect order. Except for the necessity of estimating the suction head, the test is a most satisfactory one. The owner regulated the supply of gasoline so that the governor does not cut out, the engine exploding on every working stroke. The engine had to be run a little below its full capacity during the test to avoid drowning the weir. It is the writer's opinion that the plant would have shown slightly better results at full speed.

Fuel.—No. 2 engine distillate, 47° Baumé, costing 5.25 cents per gallon.

Log of test No. 7, Lee Matthews, June 3, 1905.

No.	Time.	Revolutions per minute. Engine.	Revolutions per minute. Pump.	Explosions per minute.	Indicator card. Area.	Indicator card. Length	Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
					Sq. in.	*Inches.*	*Lbs.*		*Ins.*	*Cu. ft.*	*Feet*	
1	7.15	187	884	93	1.78	4.37	83.5	27.7	3$\frac{11}{16}$	1.10	92.3	11.5
2	7.30	189	882	95	1.84	4.40	85.7	29.1	......	......	93.6	......
3	7.45	187	879	93	1.75	4.40	81.5	27.1	3$\frac{3}{4}$	1.13	93.9	12.0
4	8.00	189	879	95	1.75	4.40	81.5	27.6	3$\frac{3}{4}$	1.13	93.9	12.0
5	8.15	188	877	94	1.74	4.40	81.1	27.2	3$\frac{3}{4}$	1.13	93.6	12.0
6	8.30	187	870	93	1.72	4.40	80.1	26.6	3$\frac{5}{8}$	1.07	93.2	11.3
7	8.45	187	874	94	1.69	4.40	78.7	26.4	3$\frac{5}{8}$	1.07	93.2	11.3
8	9.00	186	867	93	1.69	4.40	78.7	26.1	3$\frac{5}{8}$	1.07	93.0	11.3
9	9.15	186	878	93	1.65	4.40	76.9	25.5	3$\frac{11}{16}$	1.10	93.2	11.6
10	9.30	188	882	94	1.71	4.40	79.7	26.7	3$\frac{5}{8}$	1.07	93.6	11.3
11	9.45	187	878	93	1.69	4.39	78.9	26.2	3$\frac{5}{8}$	1.07	93.6	11.3
12	10.00	188	878	94	1.71	4.40	79.7	26.7	3$\frac{11}{16}$	1.10	93.8	11.7
13	10.15	186	875	93	1.63	4.40	75.9	25.2	3$\frac{5}{8}$	1.07	93.6	11.3
14	10.30	187	876	94	1.69	4.39	78.9	26.5	3$\frac{9}{16}$	1.04	93.6	11.1
15	10.45	188	878	95	1.68	4.40	78.3	26.6	3$\frac{5}{8}$	1.07	93.9	11.4
16	11.00	188	876	94	1.68	4.40	78.3	26.3	3$\frac{5}{8}$	1.07	94.3	11.4
	Mean							26.7	......	1.09	93.5	11.4

Test No. 8.—Plant Owned by the Phillips Estate, between Pomona and Spadra.

Equipment.—A 35-horsepower White & Middleton gasoline engine; cylinder, 11 by 20 inches; speed, about 180 revolutions per minute; engine starts by compressed air; pulley, 48 by 13 inches; a No. 6 compound vertical Byron Jackson centrifugal pump; one 7-inch suction pipe, 60 feet long, from a 10-inch well 275 feet deep; discharge pipe, 9-inch riveted casing; the pit is 68.5 feet deep; pulley, 12 by 16 inches; 12-inch canvas, direct, quarter-turn belt, 30 feet between centers; a 24-inch contracted rectangular weir placed in the open ditch by the testing party.

Suction lift, 23 feet (estimated); discharge lift, 67.4 feet (measured).

This plant is a type of the most modern gasoline centrifugal plants. The engine is started by compressed air, which entirely does away with the annoyance and delay of the hand methods of starting such large engines. The compressed air is kept in a cylindrical tank, about 14 by 60 inches in size, and at about 100 pounds pressure, and is furnished by a small air pump belted to the engine. The air is admitted into the cylinder by a hand-operated valve until the required speed is attained. When up to speed the compressor belt is thrown on and the air tank replenished. Of all the plants tested by our party, this was the only one found which used this convenient method of starting. The same difficulty in regard to

air carried into the suction pipe had been encountered here as in test No. 5, but the trouble had been effectually stopped by calking the top of the well casing. This, however, prevented our measuring the suction lift, and it had to be estimated in the manner described in test No. 11.

Fuel.—No. 2 engine distillate, 43° Baumé, costing 5 cents per gallon.

Log of test No. 8, Phillips estate, June 10, 1905.

No.	Time.	Revolutions per minute. Engine.	Revolutions per minute. Pump.	Explosions per minute.	Indicator card. Area.	Indicator card. Length.	Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
					Sq. in.	*Inches.*	*Lbs.*		*In.*	*Cu. ft.*	*Feet.*	
1	1.45	197	760	98	1.38	3.29	86.0	40.5	$4\frac{5}{16}$	1.38	91.6	14.3
2	2.00	198	783	98	1.44	3.29	89.7	42.2	$4\frac{1}{4}$	1.35	90.8	13.9
3	2.30	196	785	98	1.46	3.29	91.0	42.8	$4\frac{3}{16}$	1.33	90.5	13.6
4	3.00	203	765	99	1.42	3.31	87.9	41.8	$4\frac{3}{16}$	1.33	90.8	13.7
5	3.30	195	745	97	1.36	3.30	84.5	39.2	$4\frac{3}{16}$	1.33	89.9	13.5
6	4.00	202	789	99	1.41	3.31	87.3	41.5	$4\frac{1}{8}$	1.30	90.0	13.2
7	4.30	210	799	100	1.31	3.30	81.4	39.1	$4\frac{1}{8}$	1.30	89.5	13.2
8	5.00	195	755	97	1.35	3.30	83.9	39.1	......	....	90.0	......
	Mean	....	....	....	....	....	....	40.8	......	1.33	90.3	13.6

Test No. 9.—Spring Brook Plant of the Riverside Water Company.

Equipment.—A 60-horsepower Fairbanks-Morse gasoline engine; cylinder, 16.5 by 22 inches; speed about 180 revolutions per minute; pulley, 78 by 16 inches; a No. 8 single horizontal Krogh centrifugal pump; one 12-inch suction pipe about 8 feet long; no well, as the pump draws its water directly from the creek; discharge pipe 22 inches in diameter, 2,000 feet long, fitted to the pump by taper connections; a 14-inch rubber belt, 28.8 feet between centers; a $48\frac{1}{8}$-inch rectangular suppressed weir, with a velocity of approach of about 1.1 feet per second.

Suction lift, 6.5 feet (measured); discharge lift, 48.5 feet (measured); total lift, 55 feet.

This is one of the plants pumping from the bed of the Santa Ana River into the Riverside Water Company's canal.

Fuel.—No. 2 Coalinga engine distillate, costing $5\frac{1}{2}$ cents per gallon.

The exceptionally good performance of this plant seems to be due to its large size, to the good design of the pump, which was designed especially for this location, to the low suction lift, and to the simple conditions under which it is operated. The first cost ($3,500) is low on account of the absence of a well.

Log of test No. 9, Spring Brook plant, June 21, 1905.

No.	Time.	Revolutions per minute.		Explosions per minute.	Indicator card.		Mean effective pressure per square inch.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Engine.	Pump.		Area.	Length.						
					Sq. in.	*Inches.*	*Lbs.*		*In.*	*Cu. ft.*	*Feet.*	
1	9.30	180	625	67	1.41	3.55	81.4	64.8	$6\frac{1}{16}$	5.03	55.6	......
2	10.00	181	624	66	1.42	3.54	82.2	64.4	$6\frac{1}{16}$	......	......	......
3	10.30	181	626	67	1.46	3.55	84.3	67.1	6	4.96	......	......
4	11.00	181	627	66	1.43	3.59	81.6	64.0	$6\frac{1}{16}$	5.03	......	......
5	11.30	181	625	66	1.45	3.59	82.8	64.9	......	......	......	......
6	12.00	181	626	67	1.43	3.60	81.4	64.8	$6\frac{1}{16}$	5.03	54.8	......
7	12.30	181	625	65	1.45	3.60	82.6	63.8	......	......	54.8	......
8	1.00	181	625	64	1.41	3.60	80.3	61.0	$5\frac{15}{16}$	4.89	......	......
9	1.30	181	627	65	1.45	3.61	82.3	63.6	......	......	......	......
10	2.00	182	626	63	1.38	3.61	78.4	58.6	$5\frac{15}{16}$	4.89	......	......
11	2.30	181	625	63	1.40	3.62	79.3	59.3	......	......	54.8	......
12	3.00	180	625	63	1.45	3.60	82.6	61.8	......	......	......	......
13	3.30	181	626	64	1.45	3.61	82.3	62.6	$5\frac{15}{16}$	4.89	54.9	......
	Mean	......	......	......	......	......	......	63.1	......	4.96	55.0	30.9

TEST NO. 10.—PLANT OWNED BY MARTIN BROTHERS, NEAR POMONA.

Equipment.—A 25-horsepower Fairbanks-Morse gasoline engine; cylinder, 10.5 by 18 inches; pulley, 16 inches in diameter; an Addison double-acting deep-well pump with 7-inch cylinder and 24-inch stroke. Ratio of gearing, 1 to 4; diameter of discharge pipe, 6 inches; pulley, 32 inches; 12-inch canvas belt, 26 feet between centers.

No suction lift (pump below water); discharge lift, 203.5 feet. The water pump was measured by means of a cement reservoir 60 feet in diameter.

This test is of interest as showing the performance of a high-lift, deep-well pump as compared with those of the same type on low lifts. (See tests Nos. 20 and 21.) The gasoline was measured in this case by actual weight. The piping of the engine was changed so as to draw from a small tank which was weighed before and after the test. The overflow was returned to this tank.

Fuel.—No. 2 engine distillate, costing $5\frac{1}{2}$ cents per gallon; density, 0.800.

Log of test No. 10, Martin Brothers, August 31, 1905.

No.	Time.	Revolutions per minute. Engine.	Revolutions per minute. Pump.	Explosions per minute.	Indicator card. Area.	Indicator card. Length.	Mean effective pressure per square inch.	Indicated horsepower.	Discharge per second.	Measured head.	Useful water horsepower.
					Sq. in.	*Inches.*	*Pounds.*		*Cu. ft.*	*Feet.*	
1	2.15	186	22.4	59	0.95	2.92	66.7	15.5		202	
2	2.30	186	22.4	63	.99	2.94	69.0	17.1			
3	2.45	185	22.4	60	.99	2.94	69.0	16.3			
4	3.00	186	22.4	60	1.01	2.94	70.4	16.6			
5	3.15	186	22.4	56	1.03	2.92	72.3	15.9			
6	3.30	186	22.4	57	1.02	2.92	71.6	16.1			
7	3.45	186	22.4	58	1.02	2.94	71.1	16.2			
8	4.00	187	22.4	59	1.00	2.93	70.0	16.3			
9	4.15	186	22.4	68	1.09	2.94	76.0	20.3			
10	4.30	186	22.4	61	1.01	2.94	70.4	16.9			
11	4.45	186	22.4	55	1.07	2.93	74.9	16.2		205	
	Mean							16.7	0.241	203.5	5.56

Test No. 11.—Ganesha Park Municipal Plant, owned by the City of Pomona.

Equipment.—A 15-horsepower Fairbanks-Morse gasoline engine; cylinder, 8.25 by 14 inches; speed, about 250 revolutions per minute; pulley, 16 by 11 inches; a Pomona deep-well pump; pump cylinder, 7 inches in diameter; strokes, 29.5 and 25.5 inches, with a No. 18 pump head; ratio of gearing, 14 to 75; discharge pipe, 1,148 feet of 6-inch O. D. casing to a reservoir on the top of a hill. Well, 10 inches in diameter and 65 feet deep; bottom of pump cylinder, 55 feet below the surface; a 10-inch canvas belt 24.7 feet between centers.

No suction lift; discharge lift, 180.3 feet.

No weir was used in this test, the water being measured by the rise of level in the reservoir at the end of the pipe line. The mean area of the reservoir at the points where the level was read was 2,350 square feet. The total rise in level in 4 hours 41 minutes was 30.5 inches, giving a discharge of 0.354 cubic foot per second. Great difficulty was experienced in ascertaining the depth to water and the results may be in error to the extent of 4 or 5 feet. In a high-head plant of this sort, however, such error is not of serious consequence. Pumps of the above type with two pistons whose strokes overlap can not have their displacement figured by the simple formula of piston area multiplied by the length of the stroke.

Fuel.—No. 2 engine distillate, 48° Baumé; density, 0.794, costing 6 cents per gallon delivered.

Log of test No. 11, Ganesha Park, May 27, 1905.

No.	Time.	Revolutions per minute. Engine.	Revolutions per minute. Pump.	Explosions per minute.	Indicator card. Area.	Indicator card. Length.	Mean effective pressure per square inch.	Indicated horsepower.	Discharge per second.	Measured head.	Useful water horsepower.
					Sq. in.	*Inches.*	*Lbs.*		*Cu. ft.*	*Feet.*	
1	8.34.........	256	21.3	83	1.64	3.48	96.6	15.2	....	180.3	7.23
2	9.00.........	255	21.1	81	1.61	3.47	95.1	14.6	....	180.3	7.23
3	9.30.........	255	20.9	88	1.27	3.50	74.4	12.4	....	180.3	7.23
4	10.00........	254	21.1	84	1.53	3.48	90.1	14.3	....	180.3	7.23
5	10.30........	254	20.9	82	1.55	3.49	91.0	14.1	....	180.3	7.23
6	11.00........	255	20.9	83	1.54	3.49	90.5	14.2	....	180.3	7.23
7	11.30........	255	20.9	82	1.53	3.48	90.1	14.0	....	180.3	7.23
8	12.00........	254	21.1	81	1.50	3.50	87.9	13.5	....	180.3	7.23
9	12.30........	255	20.9	83	1.45	3.47	85.7	13.4	....	180.3	7.23
10	1.00.........	255	20.9	81	1.50	3.46	88.9	13.6	....	180.3	7.23
	Mean..	....	....	....	....	....	....	13.9	0.354	180.3	7.23

PLANTS DRIVEN BY ELECTRIC MOTORS.

TEST NO. 12.—PLANT OWNED BY THE SAM LEE COMPANY, NEAR POMONA.

Equipment.—A General Electric Company 15-horsepower induction motor, Type I, Form K, 60 cycles, 3-phase, 220 volts; pulley, 12 inches in diameter; Thompson polyphase meter, constant = 20. Other details of the plant as given in test No. 2, except pump pulley, which was 12 inches in diameter.

The test in this case was made with the regular Thompson recording meter, which had recently been installed, tested, and found to be correct.

Log of test No. 12, Sam Lee Company. September 26, 1905.

No.	Time.	Revolutions per minute. Motor.	Revolutions per minute. Pump.	Time of watt-meter disk.	Revolutions of watt-meter.	Kilo-watts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
				Secs.			*Inches.*	*Cu. ft.*	*Feet.*	
1	10.00.............	999	1,004	65.4	10	11.0	$3\frac{5}{16}$	0.732	....	....
2	10.15.............	1,000	1,000	65.2	10	11.0	$3\frac{5}{16}$	.732	....	....
3	10.30.............	996	990	66.0	10	10.9	$3\frac{1}{4}$	.712	....	....
4	10.45.............	996	996	66.2	10	10.9	$3\frac{1}{4}$	.712	....	....
5	11.00.............	993	995	67.0	10	10.7	$3\frac{1}{4}$	.712	....	....
6	11.15.............	996	985	67.0	10	10.7	$3\frac{1}{4}$	.712	....	....
7	11.30.............	995	988	66.6	10	10.8	$3\frac{1}{4}$	.712	....	....
8	11.45.............	991	980	66.6	10	10.8	$3\frac{1}{4}$	.712	....	....
9	12.00.............	993	983	65.0	10	11.1	$3\frac{3}{16}$	.691	....	....
	Mean......	....	....	....	....	10.8	....	.714	62	5.01

Test No. 13.—Station No. 6 of the Gage Canal Company, between Colton and Redlands.

Equipment.—A 20-horsepower General Electric induction motor, Type I, Form L; 50 cycles, 3-phase, 440 volts; pulley 12 by 12 inches; a No. 6 vertical, single Byron Jackson centrifugal pump; pulley, 20 by 20 inches; a 10-inch direct quarter-turn leather belt; a Thompson polyphase wattmeter, 50 cycles; constant = 100; a 40-inch contracted rectangular weir.

Suction lift, 19.5 feet (estimated); discharge lift, 3 feet (measured); total mean lift, 22.5 feet.

The following test was a rough one, made without the regular measuring instruments. The recording wattmeter was relied on to give the power.

$$\text{Watts} = \frac{72{,}000 \times \text{number of revolutions of disk.}}{\text{Time in seconds.}}$$

Log of test No. 13, Gage Canal, station No. 6, June 27, 1905.

No.	Time.	Revolutions per minute.		Revolutions of wattmeter.	Time of wattmeter.	Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Motor.	Pump.							
					Secs.		*Inches.*	*Cu. ft.*	*Feet.*	
1	1.30	755	447	10	78	9.23	$4\frac{3}{16}$	2.22	22.5	5.66
2	1.45			10	75	9.55	$4\frac{3}{16}$	2.22	22.5	5.66
3	2.00	755	446	10	76	9.47	$4\frac{3}{16}$	2.22	22.5	5.66
4	2.15			10	75	9.55	$4\frac{3}{16}$	2.22	22.5	5.66
5	2.30	757	446	10	78	9.25	$4\frac{3}{16}$	2.22	22.5	5.66
6	2.45			10	78	9.21	$4\frac{1}{8}$	2.17	22.5	5.53
7	3.00			10	75	9.55	$4\frac{1}{8}$	2.17	22.5	5.53
	Mean					9.40		2.21	22.5	5.62

Test No. 14.—Plant Owned by the Pomona Land and Water Company, near Pomona.

Equipment.—A 30-horsepower General Electric induction motor, Type I, Form K2; 60 cycles, 3-phase, 440 volts; wattmeter transformer ratio 5 to 1; pulley, 12.25 by 11 inches (motor running on 50 cycles); a No. 5 vertical, single-runner Byron Jackson centrifugal pump; one 5-inch and one 6-inch suction pipes from two wells; pit, 65 feet deep; discharge pipe 7.25-inch riveted casing, with one long-radius elbow; pulley, 13 by 16 inches; pump 63 feet below the surface, and entirely submerged at the time of the test; a 7.5-inch laced leather belt, quarter-turn, 28.4 feet between centers; a 30-inch rectangular, contracted weir already in place.

No suction lift (pump submerged); discharge lift, 60.3 feet (measured).

This plant is a fair average of a large number of electric centrifugals in southern California.

Log of test No. 14, Pomona Land and Water Company, May 23, 1905.

No.	Time.	Revolutions per minute.		Wattmeters.		Total kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Motor.	Pump.	Phase A.	Phase B.					
							Inches.	*Cu. ft.*	*Feet.*	
1	9.15	742	645	3.15	0.25	17.00	4	1.56	56.2	9.93
2	9.30	740	655	3.15	.26	17.05	$3\frac{5}{8}$	1.34	58.7	8.91
3	9.45	744	657	3.12	.26	16.90	$3\frac{5}{8}$	1.34	60.2	9.14
4	10.00	745	657	3.06	.24	16.50	$3\frac{1}{2}$	1.28	60.3	8.74
5	10.15	742	658	3.00	.25	16.25	$3\frac{3}{8}$	1.21	60.5	8.29
6	10.30	745	656	3.08	.25	16.65	$3\frac{7}{16}$	1.25	60.9	8.62
7	10.45	742	654	3.00	.20	16.00	$3\frac{3}{8}$	1.21	61.0	8.36
8	11.00	744	658	2.95	.25	16.00	$3\frac{5}{16}$	1.18	61.2	8.18
9	11.15	741	652	3.00	.20	16.00	$3\frac{3}{8}$	1.21	61.2	8.39
10	11.30	742	653	3.05	.15	16.00	$3\frac{3}{16}$	1.12	61.3	7.78
11	11.45	743	658	3.02	.15	15.85	$3\frac{1}{4}$	1.15	61.3	7.99
	Mean					16.38	....	1.26	60.3	8.57

Test No. 15.—Plant Owned by the West Riverside Water Company (350-inch Water Right) near Colton.

Equipment.—A 50-horsepower Westinghouse induction motor, Type C; 2,000 volts, 13.9 amperes per terminal, 3-phase, 7,200 alternations; wattmeter transformer ratio, 9.04 (2,080 to 230); pulley, 21 by 12 inches; a No. 8 compound vertical McKay centrifugal pump; no suction pipe; 14-inch discharge pipe; one 18-inch well; pulley, 15 by 13 inches; a 12-inch double, leather belt, quarter-turn with tightening pulley; a 72-inch contracted rectangular weir already in place.

No suction lift (pump under water); discharge lift, 28.4 feet (measured).

This plant was running very inefficiently. The motor was well loaded and ran hot. The pump boxes ran hot as well, but the principal loss seemed to be in the pump, which absorbed a great amount of power in proportion to its useful output. It was not possible at the time of the test to see the construction of the pump, but it was evident that the whole was contained within the 18-inch casing. The runners, therefore, must have been of rather small diameter.

Log of test No. 15, 350-inch plant, June 26, 1905.

No.	Time.	Revolutions per minute.		Wattmeters.		Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Motor.	Pump.	Phase A.	Phase B.					
							Inches.	*Cu. ft.*	*Feet.*	
1	1.30	702	908	3.15	1.40	41.1	$3\frac{1}{2}$	3.12	....	....
2	1.45	706	900	3.20	1.45	42.0	$3\frac{7}{16}$	3.03	27.8	....
3	2.00	702	902	3.00	1.40	39.8	$3\frac{3}{8}$	2.95	....	....
4	2.15	....	....	3.15	1.40	41.1	$3\frac{3}{8}$	2.95	....	....
5	2.30	708	912	3.10	1.42	40.9	$3\frac{3}{8}$	2.95	28.0	....
6	2.45	....	....	3.18	1.41	41.5	$3\frac{3}{8}$	2.95	....	....
7	3.00	709	908	3.20	1.40	41.6	$3\frac{3}{8}$	2.95	28 2	....
8	3.15	....	....	3.20	1.40	41.6	$3\frac{3}{8}$	2.95	....	....
9	3.30	....	....	3.20	1.40	41.6	$3\frac{3}{8}$	2.95	28.4	....
	Mean					41.2	....	2.97	28.1	9.45

Test No. 16.—Plant Owned by San Dimas Water Company, near San Dimas.

Immediately after test 26 had been completed (p. 37) the engine was shut down, the pulley on the pump changed to one 18 inches in diameter, and the belt thrown over to an induction motor. This was a 40-horsepower General Electric induction motor, 60 cycles, 440 volts, 3-phase, with pulley 17 inches in diameter; wattmeter transformer ratio, 275 to 110. While these changes were being made, the water in the well rose some 19 feet, so that no observations were made until the water level had fallen to the same stage as in the previous test.

The efficiency is seen to be the same for the two cases. It was observed, however, that the surface of the water in the pit was within a few inches of the suction during both runs. It is possible that air might have been drawn in during both tests. It was not possible to observe this in the discharge, as this entered a tunnel many feet distant from the weir.

Log of test No. 16, San Dimas Irrigation Company, August 5, 1905.

No.	Time.	Revolutions per minute.		Wattmeters.		Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Motor.	Pump.	Phase A.	Phase B.					
							Inches.	Cu. ft.	Feet.	
1	2.00	753	712	8.00	1.45	23.6	$3\frac{3}{4}$	1.42	94.4	....
2	2 30	760	715	8.00	1.50	23.7	$3\frac{21}{32}$	1.37	94.3	....
3	3.00	760	715	8.00	1.50	23.7	$3\frac{11}{16}$	1.38	94.3	....
4	3.30	758	712	7.95	1.55	23.7	$3\frac{11}{16}$	1.38	94.3	....
5	4.00	756	708	8.00	1.50	23.7	$3\frac{11}{16}$	1.38	94.3	....
6	4.30	759	714	8.00	1.65	24.1	$3\frac{11}{16}$	1.38	94.3	....
7	5.00	760	713	8.00	1.60	24.0	$3\frac{11}{16}$	1.38	94.3	....
	Mean	....	....	....	....	23.8	....	1.38	94.3	14.7

Test No. 17.—Plant Owned by the Currier Tract Water Company, near Pomona.

Equipment.—A 30-horsepower General Electric induction motor, Type I, Form L; 60 cycles, 3-phase, 550 volts; running on 50 cycles; wattmeter transformer, ratio 1 to 10; pulley, 13 by 11 inches; a No. 5 compound vertical Byron Jackson centrifugal pump; one 7-inch suction pipe from a 10-inch well; discharge pipe 8 inches, riveted casing; pit about 100 feet deep; pulley, 13 by 16 inches; a 10-inch direct, quarter-turn leather belt, 24.7 feet centers; a 24-inch rectangular weir partially contracted, already in place.

Suction lift, 25.1 feet (measured); discharge lift, 97.3 feet (measured); total mean lift, 122.4 feet.

The pump here used is known by the builders as the "old style" compound, where the discharge from one runner is conducted through a pipe to the inlet of the next. The performance of the plant is good, even though the belt was slipping slightly at the time of the test.

Log of test No. 17, Currier Tract Water Company, June 7, 1905.

No.	Time.	Revolutions per minute.		Wattmeters.		Kilo-watts.	Weir readings.	Discharge per second.	Measured head.	Useful water horse-power.
		Motor.	Pump.	Phase A.	Phase B.					
							Inches.	*Cu. ft.*	*Feet.*	
1	12.30	746	726	1.80	0.56	23.6	$3\frac{11}{16}$	1.10	....	....
2	1.00	739	722	1.77	.57	23.4	$3\frac{11}{16}$	1.10	121.8	....
3	1.30	744	726	1.82	.58	24.0	$3\frac{11}{16}$	1.10	....	....
4	2.00	743	720	1.78	.57	23.5	$3\frac{3}{4}$	1.13	....	....
5	2.30	743	719	1.81	.55	23.6	$3\frac{11}{16}$	1.10	122.8	....
6	3.00	743	723	1.80	.57	23.7	$3\frac{11}{16}$	1.10	....	....
7	3.30	741	722	1.77	.55	23.2	$3\frac{11}{16}$	1.10	122.2	....
8	4.00	743	725	1.83	.55	23.8	$3\frac{11}{16}$	1.10	....	....
9	4.30	742	721	1.80	.53	23.3	$3\frac{5}{8}$	1.07	122.9	....
	Mean					23.6	....	1.10	122.4	15.3

Test No. 18.—Plant Owned by the Glendora and Azusa Water Company in the San Dimas Wash.

Equipment.—A 100-horsepower Westinghouse induction motor, Type C, 400 volts, 130 amperes per terminal, 3-phase, 7,200 alternations; pulley, 42 by 16 inches. A No. 6 compound Byron Jackson centrifugal pump; one 6-inch suction from a 12-inch well, 531 feet deep. Discharge pipe of 10-inch riveted casing, with one long-radius elbow; depth of pit, 212 feet; pulley, 26 by 16 inches. Westinghouse polyphase wattmeter, 5 amperes, 400 volts; 2 Westinghouse series converters; primary, 120 amperes, secondary, 5 amperes; a 10-inch direct, quarter-turn canvas belt, 34 feet between centers; a contracted, rectangular weir, $23\frac{15}{16}$ inches wide, put in by testing party over the old 30-inch weir.

No suction lift (pump under water); discharge lift, 189 feet (measured).

This motor was too large to be tested on the indicating wattmeters used by the party. The readings of the recording wattmeter were therefore depended on to give the power input. While entire confidence can not be placed on its indications, it at least gives an exact measure of the cost of power to the owners of the plant.

$$\text{Watts} = \frac{4{,}800 \times \text{number of revolutions of disk} \times \text{transformer ratio}}{\text{time in seconds.}}$$

From the measurements obtained it would appear that this plant gave remarkably good results. It is to be regretted that a test with the Weston instruments was not possible.

The plant contained also a 75-horsepower Westinghouse motor, belted to a centrifugal pump of the same style and size as the other. No test was made on this.

Log of test No. 18, Glendora and Azusa Water Company, June 13, 1905.

No.	Time.	Revolutions per minute. Motor.	Revolutions per minute. Pump.	Revolutions of wattmeter.	Time of wattmeter	Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
					Seconds.		*Inches.*	*Cu. ft.*	*Feet.*	
1	1.00	489	787	50	101	57.1	$5\frac{19}{32}$	2.02	181.9	41.8
2	1.15			50	106	54.1	$5\frac{15}{32}$	1.95		40.8
3	1.30	488	789	50	109	52.9	$5\frac{11}{32}$	1.89	187.0	40.0
4	1.45			50	109	52.7	$5\frac{7}{32}$	1.82		38.8
5	2.00	485	787	50	114	50.6	$5\frac{5}{32}$	1.79	189.7	38.5
6	2.15			50	111	51.9	$5\frac{5}{32}$	1.79		38.5
7	2.30	489	793	50	107	53.8	$5\frac{5}{32}$	1.79	190.4	38.6
8	2.45			50	106	54.2	$5\frac{5}{32}$	1.79		38.7
9	3.00	487	792	50	111	52.0	$5\frac{5}{32}$	1.79	190.8	38.7
10	3.15			50	108	53.3	$5\frac{5}{32}$	1.79		38.7
11	3.30	488	793	50	111	52.0	$5\frac{3}{32}$	1.76	191.0	38.1
12	3.45			50	109	52.8	$5\frac{3}{32}$	1.76		38.1
13	4.00	489	794	50	108	53.4	$5\frac{3}{32}$	1.76	191.3	38.1
	Mean					53.1		1.82	188.9	39.0

Test No. 19.—Plant Owned by James Hewston, near Riverside.

Equipment.—A 10-horsepower General Electric induction motor, 60 cycles, 200 volts, 3-phase; diameter of pulley, $8\frac{1}{2}$ inches; a No. 7 Quimby screw pump; discharge pipe, 8-inch riveted casing, about 1,000 feet long, with one check valve and three short-radius elbows; suction pipe 6 inches in diameter and about 6 feet long; no well; an 8-inch canvas belt, 13 feet between centers; a 10-inch rectangular weir with end contractions.

Suction lift, 4.7 feet (measured); discharge lift, 33.5 feet (measured); total mean lift, 38.2 feet (measured); constant total lift as shown by pressure gauge at pump, 52.3 feet.

This pump drew its water from a sump about 6 feet deep, which in turn was connected to a canal by 50 feet of 8-inch pipe. The discharge pipe was laid on a gradual incline to the top of a hill, where the weir was located. The head pumped against was measured with a pressure gauge, and the lift was leveled up by means of a Y level. The difference between the two is so great as to indicate an obstruction of some sort in the pipe. The hydraulic horsepower of the pump, calculated from the reading of the pressure gauge, was 2.92. Combined efficiency of motor and pump, $\frac{2.92}{7.16}=41$ per cent.

Log of test No. 19, James Hewston, June 30, 1905.

No.	Time.	Revolutions per minute. Motor.	Revolutions per minute. Pump.	Wattmeters. Phase A.	Wattmeters. Phase B.	Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
							Inches.	*Cu. ft.*	*Feet.*	
1	4.45	992	533	1.20	4.00	5.20	4	0.492	38.2	2.13
2	5.00	991	535	1.25	4.10	5.35	4	.492	38.2	2.13
3	5.15			1.30	4.10	5.40	4	.492	38.2	2.13
4	5.30	992	532	1.35	4.05	5.40	4	.492	38.2	2.13
5	5.45			1.30	4.05	5.35	4	.492	38.2	2.13
	Mean					5.34		.492	38.2	2.13

Test No. 20.—Station No. 1 of the Consolidated Water Company of Pomona.

Equipment.—A 10-horsepower General Electric induction motor, Type I, Form L, 60 cycles, 3-phase, 440 volts; pulley, 8 by 6 inches (running on 50 cycles); a deep-well Lindsay & Addison piston pump; pump cylinder, 7 inches in diameter and about 2-foot stroke; ratio of gearing, 4 to 1; well, 9 inches in diameter; pulley, 72 by 8.5 inches; Thompson polyphase wattmeter, 440 volts, 25 amperes, 50 cycles; constant = 100; an 18-inch contracted rectangular weir; a 6-inch double, leather belt.

Lift, 63 feet (estimated).

$$\text{Watts} = \frac{72{,}000 \times \text{number of revolutions of disk}}{\text{time in seconds.}}$$

It was found impossible to measure accurately the lift of this plant. The above figure is obtained from plants in the immediate vicinity, and from the estimate of the attendant. It may be in error 10 per cent. The test is in this regard, of course, unsatisfactory.

Log of test No. 20, Station No. 1, of Consolidated Water Company, June 16, 1905.

No.	Time.	Revolutions per minute. Motor.	Revolutions per minute. Pump.	Revolutions of wattmeter.	Time of wattmeter.	Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
					Seconds		*Inches.*	*Cu. ft.*	*Feet.*	
1	9.45	1,000	28.8	10	107	6.72	$2\frac{5}{16}$	0.412		
2	10.00			10	111	6.49	$2\frac{7}{16}$	.444		
3	10.15						$2\frac{3}{8}$	.428		
4	10.30	1,007	28.8	10	114	6.33	$2\frac{3}{8}$	.428		
5	10.45			10	114	6.30	$2\frac{3}{8}$	.428		
6	11.00	1,007	28.8	10	115	6.26	$2\frac{3}{8}$	.428		
7	11.15			10	116	6.20	$2\frac{7}{16}$	.444		
8	11.30	1,007	28.8	10	120	5.98	$2\frac{7}{16}$	.444		
9	11.45	1,006	28.8	10	120	6.00	$2\frac{3}{8}$	.428		
	Mean					6.28		.432	63	3.08

Test No. 21.—Station No. 3 of the Consolidated Water Company of Pomona.

Equipment.—A 20-horsepower General Electric induction motor, Type I, Form K, 60 cycles, 3-phase, 440 volts; pulley, 11 by 8.5 inches; a deep-well Lindsay & Addison piston pump; pump cylinder 10 inches in diameter and about 2-foot stroke; ratio of gearing, 12 to 1; pulley, 30 by 8 inches; an 18-inch, double, leather belt, 21.6 feet between centers; a Thompson polyphase wattmeter, 50 cycles, 25 amperes, 440 volts; constant = 100; an 18-inch contracted, rectangular weir, put in by the testing party over the old weir.

Lift, 63 feet (measured).

It was found impossible on this, as well as on all other motor-driven, reciprocating pumping plants, to measure the electric power

on the Weston instruments, on account of the fluctuations of the needle. Since dead-beat instruments were not procurable the readings of the recording meter had to be taken by counting the revolutions of its disk.

$$\text{Watts} = \frac{72{,}000 \times \text{number of revolutions of disk}}{\text{time in seconds}}.$$

The lift was measured by a float let down between the well casing and discharge pipe. This was a fairly satisfactory test on a deep-well plant, a type on which it is most difficult to get reliable results.

Log of test No. 21, Consolidated Water Company's Station No. 3, May 27, 1905.

No.	Time.	Revolutions per minute.		Revolutions of wattmeter.	Time of wattmeter.	Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Motor.	Pump.							
					Seconds.		*Inches.*	*Cu. ft.*	*Feet.*	
1	9.45	748	22.8	20	87	9.81	....	....	61.8	5.29
2	10.00	742	22.7	20	90	9.62	$3\frac{1}{2}$	0.756	62.3	5.34
3	10.15	745	22.6	20	89	9.69	$3\frac{1}{2}$	.756	62.7	5.37
4	10.30	742	22.7	20	88	9.74	$3\frac{1}{2}$	.756	63.1	5.40
5	10.45	744	22.7	20	86	9.86	$3\frac{15}{32}$	.746	63.3	5.35
6	11.00	744	22.6	20	87	9.81	$3\frac{15}{32}$	.746	63.3	5.35
7	11.15	742	22.6	20	88	9.73	$3\frac{15}{32}$	.746	63.5	5.37
8	11.30	745	22.5	20	87	9.80	$3\frac{15}{32}$	.746	63.6	5.37
	Mean	....	....	....	....	9.76	....	.750	63.0	5.36

Test No. 22.—Plant Owned by the Excelsior Land Company near Riverside.

Equipment.—A 20-horsepower General Electric induction motor, Type I, Form A, 50 cycles, 3-phase, 550 volts; pulley, 13 by 9 inches; Deane triplex, plunger pump, with plungers 8 inches in diameter and 10-inch stroke; two 6-inch suctions from two 10-inch wells; an 8-inch discharge line up a hill to the weir on the upper ditch; gearing, 4.8 to 1; pulley, 42 by 12 inches; Thompson polyphase wattmeter, 25 amperes, 550 volts, 50 cycles; K=25; an 18-inch Cipolletti weir put in by the testing party of the previous year; an 8-inch, double, leather belt.

Suction lift, 9 feet (measured); discharge lift, 66 feet (measured); total head, 75 feet.

$$\text{Watts} = \frac{25 \times 3{,}600 \times \text{number of revolutions of disk}}{\text{time in seconds}}.$$

This plant, as in the case of deep-well plants, could not be measured with the Weston wattmeters. The recording instrument was therefore relied on. This plant gave an excellent efficiency, even on the head of 75 feet, which is low for a triplex. The whole installation is well designed and constructed.

Log of test No. 22, Excelsior Land Company, June 28, 1905.

No.	Time.	Revolutions per minute.		Time of watt-meter.	Revolutions of watt-meter.	Kilo-watts.	Weir readings.	Discharge per second.	Measured head.	Useful water horse-power.
		Motor.	Pump.							
				Seconds.			*Inches.*	*Cu. ft.*	*Feet.*	
1	9.45	756	236	109	10	8.27				
2	10.00	751	234	109	10	8.27				
3	10.15			109	10	8.26	$3\frac{3}{16}$	0.691		5.87
4	10.30	754	237	118	11	8.38	$3\frac{3}{16}$	.691		5.87
5	10.45			109	10	8.27				
6	11.00	755	235	108	10	8.32	$3\frac{3}{16}$	.691		5.87
7	11.15			110	10	8.20				
8	11.30	751	235	110	10	8.15	$3\frac{3}{16}$	.691		5.87
9	11.45			119	11	8.33	$3\frac{3}{16}$	.691		5.87
10	12.00			106	10	8.47				
	Mean					8.29		.691	75	5.87

Tests Nos. 23 and 24.—Plant Owned by Meacham and Castleman, Riverside.

Equipment.—A 15-horsepower General Electric induction motor, Type 1, 60 cycles, 3-phase, 200 volts; diameter of pulley, 8 inches; a Root rotary pump, No. 1, with a 6-inch suction pipe and 7-inch discharge; the pump is mounted with axis horizontal in a dug well 5 by 8 feet in cross section; there is no bored well; length of suction pipe, 19½ feet; diameter of the pulley, 32 inches; a 7-inch canvas belt extending almost vertically to the pump with 30-foot centers; a 10-inch rectangular weir fully contracted.

Mean suction lift, 19 feet; discharge lift, 79.1 feet; total mean lift, 98.1 feet.

The pump in this plant was mounted on a platform in a pit about 28 feet below the surface. The impellers consist of two 2-lobed wheels geared together and furnish a positive discharge. After reaching the surface the water is forced through a pipe line about 150 feet long to a weir box some 51 feet higher. The pump is too large to run at its full capacity continuously, and therefore the level of the water in the well falls until air is taken through the suction and the discharge cut down. Two tests were therefore made. The first, No. 23, represents the performance of the pump before the water fell below the suction pipe and therefore shows the action at full capacity. The second, No. 24, shows the performance when air is being drawn through the suction and represents more nearly the usual working conditions.

Log of tests Nos. 23 and 24, Meacham and Castleman, June 30, 1905.

TEST NO. 23.

No.	Time.	Revolutions per minute.		Wattmeters.		Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
		Motor.	Pump.	Phase A.	Phase B.					
							Inches.	*Cu. ft.*	*Feet.*	
1	11.00	1,007	....	2.50	7.50	10.00	$5\frac{3}{8}$	0.742	85.1	7.15
2	11.15	1,006	261	2.50	7.45	9.95	$5\frac{3}{8}$	.742	86.6	7.28
3	11.30	....	....	2.70	7.55	10.25	$5\frac{3}{8}$	.742	88.1	7.41
4	11.45	1,010	263	2.75	7.55	10.30	$5\frac{3}{8}$	.742	89.9	7.56
5	12.00	1,013	....	2.75	7.70	10.45	$5\frac{3}{8}$	.742	94.3	7.93
	Mean	....	....	....	....	10.19	....	.742	88.8	7.46

TEST NO. 24.

No.	Time.	Motor.	Pump.	Phase A.	Phase B.	Kilowatts.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
1	12.15	1,011	261	3.00	7.80	10.80	$5\frac{1}{8}$	0.696	96.6	7.62
2	12.30	....	262	3.40	8.30	11.70	5	.673	98.6	7.52
3	12.45	....	....	3.50	8.30	11.80	5	.673	98.6	7.52
4	1.00	....	....	3.40	8.30	11.70	5	.673	98.6	7.52
	Mean	....	....	....	....	11.50	....	.679	98.1	7.55

STEAM-DRIVEN PUMPING PLANTS.

TEST NO. 25.—PLANT OWNED BY THE ARTESIAN BELT WATER COMPANY, SAN DIMAS.

Equipment.—A 75-horsepower simple noncondensing Atlas steam engine; cylinder, 10 by 16 inches; rod, 1.75 inches; automatic slide valve with shaft governor; speed, about 190 revolutions per minute; diameter of pulley, 84 inches; one plain, horizontal return tubular boiler, 54 inches in diameter by 12 feet long; one feed-water heater supplied by gravity from a tank which in turn was filled by a direct-acting steam pump; one duplex boiler feed pump; a No. 5 vertical compound Byron Jackson centrifugal pump; suction pipe consists of 6-inch O. D. casing from a 12-inch well, 360 feet deep; the discharge is 7-inch casing; pulley 15.5 inches in diameter; a 10-inch direct canvas belt drive, 32 feet centers; a 30-inch contracted rectangular weir.

Suction lift, about 32 feet (estimated); discharge lift, 132 feet (measured); total lift, 164 feet. Scale of indicator spring 61.5 pounds; the suction lift could not be satisfactorily measured in this plant. A rubber tube lowered 29 feet did not reach water and it was necessary to estimate the suction by the vacuum gauge. The error due to this method in so high a lift will not be great.

Fuel.—Crude oil, 18° Baumé, costing 75 cents per barrel.

Log of test No. 25, Artesian Belt Water Company, July 21, 1905.

No.	Time.	Revolutions per minute.		Area of card.			Mean effective pressure per square inch.		Indicated horsepower.	Weir readings	Discharge per second.	Measured head.	Useful water horsepower.
		Engine.	Pump.	Head.	Crank.	Length.	Head.	Crank.					
				Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*		*In.*	*Cu. ft.*	*Feet.*	
1	12.00......	190	1,001	1.34	1.48	3.25	25.4	28.0	31.7	$2\frac{1}{16}$	0.586	......	......
2	12.30.......	191	....	1.32	1.50	3.26	24.9	28.3	31.8	2	.560	......	......
3	1.00........	191	....	1.31	1.53	3.26	24.7	28.9	32.0	2	.560	......	......
4	1.30........	192	1,002	1.32	1.50	3.26	24.9	28.3	31.8	$2\frac{1}{16}$	.586	......	......
5	2.00........	191	1,005	1.30	1.53	3.25	24.6	29.0	32.0	$2\frac{1}{16}$	.536	......	......
6	2.30........	192	1,003	1.31	1.48	3.26	24.7	27.9	31.6	$2\frac{1}{16}$	.586	......	......
7	3.00........	192	1,005	1.33	1.45	3.26	25.1	27.4	31.5	$2\frac{1}{16}$	.586	......	......
	Mean.	......	......	......	......	......	....	....	31.8	......	.578	164	10.7

Test No. 26.—Plant Owned by the San Dimas Irrigation Company, near San Dimas.

Equipment.—A 35-horsepower simple noncondensing Atlas steam engine, with slide valve and automatic-shaft governor; cylinder, 9 by 12 inches; rod, $1\frac{5}{8}$ inches; speed, about 220 revolutions per minute; pulley, 42 inches; boiler and auxiliaries, same as in test No. 36; a No. 5 vertical compound Byron Jackson centrifugal pump; 8-inch discharge pipe; 13-inch pulley; a 9.5-inch canvas belt, 34 feet between centers; $61\frac{1}{2}$ spring in indicator; a 30-inch rectangular weir with end contractions.

No suction lift (pump under water); discharge lift, 94.3 feet.

Fuel.—Crude oil 18° Baumé, costing 75 cents per barrel.

This plant is located in the same building with the air compressor described in No. 36. The following test was made with the steam engine belted to the centrifugal pump, and later another test was made (No. 16) with an electric motor bolted to the same pump and under identical conditions as to head and nearly identical conditions as to speed. The comparison is of great interest. Combined efficiency of piping and pump $\frac{14.7}{26.5}=55$ per cent. Mechanical efficiency of engine (approximate) $\frac{26.5}{31.7}=83.6$ per cent.

Log of test No. 26, San Dimas Irrigation Company, August 5, 1905.

No.	Time.	Revolutions per minute. Engine.	Revolutions per minute. Pump.	Area of card. Head.	Area of card. Crank.	Area of card. Length.	Mean effective pressure per square inch. Head.	Mean effective pressure per square inch. Crank.	Indicated horsepower.	Weir readings.	Discharge per second.	Measured head.	Useful water horsepower.
				Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*		*In.*	*Cu. ft.*	*Feet.*	
1	9.00	221	702	1.73	1.87	2.89	36.8	39.8	32.1	$3\frac{21}{32}$	1.37	94.3	......
2	9.30	221	705	1.74	1.85	2.88	37.1	39.5	32.1	$3\frac{21}{32}$	1.37	94.3	......
3	10.00	222	705	1.79	1.86	2.89	38.1	39.6	32.7	$3\frac{11}{16}$	1.38	94.2	......
4	10.30	220	695	1.72	1.84	2.89	36.6	39.2	31.6	$3\frac{11}{16}$	1.38	94.3	......
5	11.00	222	706	1.71	1.83	2.88	36.5	39.1	31.9	$3\frac{21}{32}$	1.37	94.3	......
6	11.30	219	694	1.67	1.83	2.88	35.6	39.1	31.0	$3\frac{11}{16}$	1.38	94.4	......
7	12.00	221	700	1.70	1.81	2.88	36.3	38.6	31.4	$3\frac{21}{32}$	1.37	94.3	......
	Mean	......	......	......	......	......	......	......	31.7	......	1.37	94.3	14.7
8	3.05	228	......	.10	.46	2.90	2.1	9.8	5.1	Belt off.			
9	3.10	229	......	.10	.47	2.89	2.1	10.0	5.2	Friction of engine.			
	Mean	......	......	......	......	......	......	......	5.2	Net horsepower=26.5.			

Test No. 27.—Plant Owned by the Western Water and Power Company in the San Dimas Wash.

Equipment.—Simple Corliss condensing steam engine; size of cylinder, 10.5 by 30 inches, with piston rod $2\frac{3}{8}$ inches; the engine uses a single wrist-plate; diameter of the fly wheel, 9 feet, with an 18-inch face, used for a belt wheel; two Heine water-tube boilers of about 100 horsepower capacity each and carrying 140 pounds of steam pressure; only one is used, the other being held in reserve; a Worthington duplex oil pump, 3 by 2.75 by 3 inches; a duplex feed pump, 4.5 by 3 by 4 inches; a surface condenser containing about 300 square feet of cooling surface; a Worthington duplex air pump, 6 by 5.75 by 6 inches; a No. 3 Byron Jackson centrifugal circulating pump driven from the jack shaft; a No. 6 vertical compound Byron Jackson centrifugal pump; one suction, 9 inches in diameter from a 12-inch well; discharge pipe, 10.5-inches, riveted casing; the pit is 200 feet deep and the pump is situated about 190 feet below the surface; pulley, 24 by 16 inches; a 16-inch double leather belt from the engine fly wheel to a 30-inch pulley on the jack shaft, with a 24-inch tightener between; a 48-inch pulley on the jack shaft is belted with a 12-inch double leather belt by a quarter-turn to the pump; the center distance from engine to jack shaft is 19.7 feet; from the jack shaft to the pump, 29 feet. Weir No. 1 is an 18-inch rectangular, fully contracted, and put in place by the testing party over the old 20-inch weir, whose contractions were imperfect. Weir No. 2 is a suppressed weir $37\frac{3}{16}$ inches wide, already in place. Pump discharge was the sum of the two weir measurements; steam pressure (average), 134 pounds; vacuum gauge on condenser, 21 inches; vacuum gauge on pump, 24 inches.

Suction lift, 17.8 feet (measured); discharge lift, 195.6 feet (meas-

ured); total mean lift, 213.4 feet; scale of indicator spring, 61.5 pounds.

The plant also contains a 16 by 36 Savage Corliss engine, which can be belted to the jack shaft above described, and also contains a 12-foot sheave for a wire-rope drive to another and similar pump and pit to the east of the power house. This machinery was not in use at the time of the test.

Fuel.—Crude oil of 18° Baumé; density, 0.948, at 80 cents per barrel (nominal).

This steam plant has been installed at considerable expense and is well operated. It has points in its design, however, which seem to account in part for its comparatively low-plant efficiency. In the first place, the back-pressure line of the indicator card barely passes below the atmospheric line at one point of the stroke, showing two small or throttled passages to the condenser, where the vacuum gauge showed 21 inches. In other words, the condenser might have been dispensed with, with small loss of power and the steam consumption of a duplex air pump and the loss in the circulating pump saved. In the second place, the heavy jack shaft with short-center distance and tightening pulley certainly absorbed considerable power.

Log of test No. 27, Western Water and Power Company, June 14, 1905.

No.	Time.	Revolutions per minute.		Area of card.			Mean effective pressure per square inch.		Indicated horsepower.	Weir No. 1.		Weir No. 2.		Measured head.	Useful water horsepower.
		Engine.	Pump.	Head.	Crank.	Length.	Head.	Crank.		Reading.	Discharge per second.	Reading.	Discharge per second.		
				Sq. in.	Sq. in.	In.	Lbs.	Lbs.		In.	Cu. ft.	In.	Cu. ft.	Feet.	
1	11.00......	118.0	802	3.23	3.12	2.73	72.8	70.3	108.0	$3\frac{7}{8}$	0.88	$2\frac{3}{16}$	0.82	......	.....
2	11.30......	118.0	800	3.25	3.12	2.73	73.2	70.3	108.3	$3\frac{7}{8}$	.88	$2\frac{3}{16}$	.82	212.6	.....
3	12.00......	118.0	801	3.17	3.11	2.72	71.7	70.3	107.2	$3\frac{15}{16}$	.90	$2\frac{3}{16}$	.82	......	.....
4	12.30......	118.3	806	3.25	3.12	2.73	73.2	70.3	108.5	$3\frac{15}{16}$	.90	$2\frac{3}{16}$	.82	......	.....
5	1.00.......	118.3	805	3.21	3.07	2.73	72.3	69.2	107.0	$3\frac{15}{16}$	.90	$2\frac{3}{16}$	.82	......	.....
6	1.30.......	118.3	800	3.22	3.12	2.73	72.5	70.3	108.1	$3\frac{15}{16}$	.90	$2\frac{3}{16}$	.82	......	.....
7	2.00.......	118.0	803	3.23	3.11	2.73	72.8	70.1	107.8	$3\frac{15}{16}$	.90	$2\frac{3}{16}$	.82	......	.....
8	2.30.......	118.2	803	3.23	3.12	2.74	72.5	70.0	107.9	$3\frac{15}{16}$	.90	$2\frac{3}{16}$	.82	......	.....
9	3.00.......	118.0	802	3.22	3.05	2.73	72.5	68.7	106.6	$3\frac{7}{8}$	.88	$2\frac{3}{16}$	.82	......	.....
10	3.30.......	118.0	803	3.27	3.10	2.73	73.7	69.8	108.1	$3\frac{7}{8}$	.88	$2\frac{3}{16}$	.82	......	.....
11	4.00.......	118.2	804	3.27	3.09	2.74	73.4	69.4	108.1	$3\frac{7}{8}$	.88	$2\frac{3}{16}$	.82	214.2	.....
	Mean..	......	...	......	......	......	......	......	107.8	....	.89	....	.82	213.4	41.3

TESTS NOS. 28, 29, AND 30.—PLANT OWNED BY THE LISBON RECLAMATION DISTRICT NO. 307, NEAR CLARKSBURG LANDING, SACRAMENTO COUNTY.

NO. 1 UNIT (LEFT-HAND ENGINE).

Equipment.—A vertical, triple expansion, condensing steam engine; size of cylinders, 8 and 12 and 22 by 16 inches; rods 1.5 inches on high pressure and 2 inches on intermediate pressure and low pressure. High and intermediate cylinders in tandem; low on separate crank; piston and slide valves; a No. 30 single horizontal centrifugal pump direct connected to engine; two 20-inch suction openings and pipes, uniting into a single 36-inch suction, 140 feet long to the end of the canal; 193 feet of the discharge pipe 36 inches in diameter, with a taper reducer to the pump 9 feet long; discharge extending over the levee and down to the river; pump runner 42 inches in diameter.

NO. 2 UNIT (RIGHT-HAND ENGINE).

Equipment.—Exactly like No. 1, except the cylinder diameters, which are 8.5 and 12.75 and 22 by 16 inches. Pump similar to No. 1, except that the pump runner is 40 inches in diameter; two Worthington oil pumps 4.5 by 2.75 by 4 inches; two Dow combined air and feed pumps, and one duplex feed pump; two jet condensers; two sets of Babcock and Wilcox water-tube boilers built for 140 pounds pressure and equipped with Witt patent burners; 80-pound indicator spring on high-pressure cylinder; 39.9-pound indicator spring on intermediate cylinder; 20-pound indicator spring on low-pressure cylinder.

Suction lift, 13.54 feet (leveled); discharge lift, − 0.06 foot (leveled); total mean lift, 13.48 feet (leveled).

Fuel.—Crude oil at 85 cents per barrel.

This plant, it will be seen, is quite differently designed from the next. The pumps carry the water through something like 340 feet of 36-inch pipe. The discharge is over the front levee into the Sacramento River. The first test on No. 1 is hardly a fair one so far as the boiler is concerned, and the furnace had not become thoroughly heated up when the test began. The plant, however, seems to consume too much oil for the output. Whether this was the fault of the boilers or the engine was not determined, as there was no method of measuring the evaporation of the boiler without making extensive changes. The performance of the pump was remarkably good.

No. 1 unit. Efficiency of pump and piping $\frac{83.7}{133.3} = 63$ per cent.

No. 2 unit. Efficiency of pump and piping $\frac{78.9}{123.3} = 64$ per cent.

Log of test No. 28, Lisbon plant, No. 1 unit (left-hand engine), May 8, 1905.

No.	Time.	Revolutions of engine.	Area of high-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of high pressure.	Area of intermediate-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of intermediate pressure.
			Head.	Crank.	Length.	Head.	Crank.		Head.	Crank.	Length.	Head.	Crank.	
			Sq. in.	*Sq. in.*	*In.*	*Lbs.*	*Lbs.*		*Sq. in.*	*Sq. in.*	*In.*	*Lbs.*	*Lbs.*	
1	8.00......	140	......	......	......	......	......	......	0.20	0.20	3.90	2.05	2.05	2.6
2	8.07......	142	2.97	3.06	3.85	61.7	63.6	35.5	3.22	2.88	3.93	32.7	29.2	39.3
3	8.30......	141	2.71	2.71	3.89	55.7	55.7	31.3	2.91	2.50	3.91	29.7	25.5	34.8
4	9.15......	140	2.83	2.93	3.90	58.0	60.1	33.0	3.25	2.74	3.96	32.7	27.6	37.8
5	9.30......	140	2.93	2.98	3.91	59.9	61.0	33.8	3.34	2.84	3.92	34.0	28.9	39.4
6	10.00......	140	2.81	2.87	3.85	58.4	59.6	33.0	3.22	2.73	3.91	32.9	27.9	38.1
7	10.30......	140	2.71	2.71	3.85	56.3	56.3	31.5	3.13	2.64	3.90	32.0	27.0	36.9
8	11.00......	140	2.80	2.84	3.85	58.2	59.0	32.8	3.22	2.77	3.90	32.9	28.3	38.3
9	11.30......	140	2.78	2.81	3.85	57.8	58.4	32.5	3.15	2.66	3.90	32.2	27.2	37.2

No.	Time.	Area of low-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of low pressure.	Total indicated horsepower.	Mean discharge per second.	Leveled head.	Useful water horsepower.
		Head.	Crank.	Length.	Head.	Crank.					
		Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*			*Cu. feet.*	*Feet.*	
1	8.00......	0.15	0.13	3.80	0.79	0.68	3.1	5.7	....	Friction load.	
2	8.07......	3.27	3.25	3.88	16.9	16.8	73.2	148	....	13.47	83.6
3	8.30......	2.91	2.67	3.87	15.0	13.8	62.1	128	....	13.45	83.4
4	9.15......	2.91	2.82	3.86	15.1	14.6	63.6	134	....	13.49	83.7
5	9.30......	3.30	3.11	3.86	17.1	16.1	71.1	144	....	13.47	83.6
6	10.00......	3.23	3.17	3.87	16.7	16.4	70.9	142	....	13.52	83.9
7	10.30......	3.01	2.87	3.75	16.1	15.3	67.2	136	....	....	....
8	11.00......	3.04	3.12	3.75	16.2	16.6	70.2	141	....	13.50	83.8
9	11.30......	3.10	2.91	3.75	16.5	15.5	68.5	138	....	....	....
	Mean.	....	....	....	....	....	....	139	54.77	13.48	83.7

Log of test No. 29, Lisbon plant, No. 2 unit (right-hand engine), May 8, 1905.

No.	Time.	Revolutions of engine.	Area of high-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of high pressure.	Area of intermediate-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of intermediate pressure.
			Head.	Crank.	Length.	Head.	Crank.		Head.	Crank.	Length.	Head.	Crank.	
			Sq. in.	*Sq. in.*	*In.*	*Lbs.*	*Lbs.*		*Sq. in.*	*Sq. in.*	*In.*	*Lbs.*	*Lbs.*	
1	1.15......	150	......	......	......	......	......	......	0.11	0.09	3.89	1.1	0.9	1.5
2	1.30......	150	3.31	3.12	3.81	69.5	65.5	45.7	2.35	2.17	3.82	24.5	22.7	35.8
3	2.00......	152	3.23	3.11	3.84	67.3	64.8	45.3	2.36	2.10	3.84	24.5	21.8	35.6
4	2.30......	150	3.16	3.06	3.84	65.8	63.8	43.9	2.34	2.17	3.81	24.5	22.7	35.8
5	3.00......	150	3.26	3.08	3.84	67.9	64.2	44.7	2.35	2.17	3.82	24.5	22.7	35.8
6	3.30......	150	3.09	2.93	3.85	64.2	60.9	42.4	2.19	2.04	3.84	22.8	21.2	33.4
7	4.00......	148	3.23	3.06	3.85	67.1	63.6	43.7	2.23	2.02	3.82	23.3	21.1	33.3

Log of test No. 29, Lisbon plant, No. 2 unit (right-hand engine), May 8, 1905—Cont'd.

No.	Time.	Area of low-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of low pressure.	Total indicated horsepower.	Mean discharge per second.	Leveled head.	Useful water horsepower.
		Head.	Crank.	Length.	Head.	Crank.					
		Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*			*Cu. feet.*	*Feet.*	
1	1.15	0.37	0.41	3.90	1.9	2.1	9.2	10.7		Friction load.	
2	1.30	2.22	2.50	3.90	11.4	12.8	55.5	137		13.41	79.0
3	2.00	2.33	2.48	3.93	11.9	12.6	57.0	138		13.41	79.0
4	2.30	2.14	2.34	3.89	11.0	12.0	52.8	133		13.39	78.9
5	3.00	2.03	2.23	3.89	10.4	11.5	50.2	131		13.39	78.9
6	3.30	2.18	2.34	3.91	11.1	12.0	53.0	129		13.37	78.8
7	4.00	2.43	2.62	3.90	12.5	13.4	58.6	136		13.37	78.8
	Mean.							134	52.02	13.39	78.9

This is one of the largest and best equipped of the reclamation plants on the Sacramento River. Instead of pumping over the front levee into the river, the discharge is over the back levee into the tules, giving the minimum lift. The canal is brought under the engine house itself, giving a short, direct suction lift, and the plant is built against the levee, giving the shortest possible discharge. By these means the lowest possible lift, together with the minimum frictional loss in pipes, is secured. The water was measured by gauging the main canal with a Price current meter.

No. 1 unit. Efficiency of pump and piping $\frac{106.4}{191}=56$ per cent.

No. 2 unit. Efficiency of pump and piping $\frac{96.4}{193}=50$ per cent.

Tests Nos. 31 and 32.—Drainage Plant Owned by the Pearson Reclamation District near Vorden Landing, Sacramento County.

No. 1 Unit.

Equipment.—A cross-compound condensing Byron Jackson steam engine; size of cylinders, 16.25 and 28 by 20 inches; rods $3\frac{1}{8}$ inches in diameter; single piston valve distributing steam to both cylinders. A No. 40 single horizontal Byron Jackson centrifugal pump, direct connected to the engine; single vertical 44-inch suction pipe to the pump; discharge pipe 44 inches in diameter, connected by taper reducer to the pump and passing over the top of the levee.

No. 2 Unit.

Equipment.—Tandem compound condensing steam engine; size of cylinders, 16 and 26 by 18 inches; rods $2\frac{7}{8}$ inches on high pressure (in front) and 2.5 inches on low pressure (in rear); a piston valve on the high-pressure and a plain slide on the low-pressure cylinder. A No.

30 single horizontal centrifugal pump. It has two 29-inch suction pipes, one at each side of the pump. The discharge pipe is 40 inches in diameter, connected by a taper reducer, and to a conical diffuser.

No. 3. Unit.

Equipment.—A cross-compound vertical condensing steam engine and horizontal centrifugal pump, not measured nor tested by our party; a Jackson air pump, belted to a line shaft, which can be run from any of the units; jet condensers; a duplex feed pump, and a Dow duplex oil pump; three return tubular boilers, with oil burners, capable of handling two of the units at once; 39.9-pound indicator spring on high-pressure cylinder; 19.7 and 20.8 pound springs on low-pressure cylinder. Suction lift, about 15 feet; discharge lift, about —5 feet (siphon action); total mean lift, 9.8 feet (leveled).

Fuel.—Crude oil at 90 cents per barrel, 25° Baumé.

Log of test No. 31, Vorden pumping plant, No. 1 unit, April 9, 1905.

No.	Time.	Revolutions per minute of engine.	Area of high-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of high pressure.	Area of low-pressure card.		
			Head.	Crank.	Length.	Head.	Crank.		Head.	Crank.	Length.
			Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*		*Sq. in.*	*Sq. in.*	*Inches.*
1	9.00	155	1.03	0.97	3.16	13.0	12.2	40.2	0.04	0.21	3.13
2	9.15	154	2.82	2.73	3.19	35.3	34.2	110	2.43	2.39	3.19
3	9.30	154	2.74	2.69	3.19	34.3	33.7	108	2.54	2.35	3.18
4	9.45	153	2.82	2.65	3.19	35.3	33.2	108	2.41	2.25	3.19
5	10.00	155	2.97	2.69	3.17	37.4	33.9	114	2.41	2.27	3.18
6	10.15	155	2.79	2.73	3.18	35.0	34.2	110	2.30	2.28	3.19
7	10.30	153	2.83	2.67	3.19	35.4	33.4	108	2.36	2.18	3.20
8	10.45	153	2.71	2.62	3.17	34.1	33.0	106	2.13	2.00	3.11
9	11.00	154	2.78	2.65	3.17	35.0	33.4	108	2.15	2.02	3.14
10	11.15	151	2.72	2.55	3.17	34.2	32.1	103	1.94	1.95	3.15
11	11.30	155	2.82	2.68	3.16	35.6	33.8	111			
12	11.45	150	2.65	2.62	3.17	33.4	33.0	102	2.08	1.96	3.17
13	12.00	155	2.81	2.73	3.17	35.4	34.4	111	2.11	1.93	3.16
14	12.15	153	2.71	2.59	3.16	34.2	32.7	105	2.00	1.95	3.16
15	12.30	150	2.82	2.70	3.17	35.5	34.0	107	2.13	1.96	3.17
	Mean.										

No	Time.	Mean effective pressure per square inch.		Indicated horsepower of low pressure.	Total indicated horsepower.	Mean discharge per second.	Leveled head.	Useful water horsepower.
		Head.	Crank.					
		Pounds.	*Pounds.*			*Cubic feet.*	*Feet.*	
1	9.00	0.25	1.32	7.56	7.8		Friction load.	
2	9.15	15.0	14.8	142	252			
3	9.30	15.7	14.6	144	252		9.72	
4	9.45	14.9	13.9	136	244			
5	10.00	14.9	14.1	139	253			
6	10.15	14.2	14.1	136	246			
7	10.30	14.5	13.4	132	240		9.88	
8	10.45	14.2	13.4	131	237			
9	11.00	14.2	13.4	131	239			
10	11.15	12.8	12.9	120	223			
11	11.30							
12	11.45	13.6	12.9	123	225			
13	12.00	13.9	12.7	127	238		9.90	
14	12.15	13.2	12.8	123	228			
15	12.30	14.0	12.9	125	232		9.92	
	Mean.				239	95.4	9.85	106.4

Log of test No. 32, Vorden pumping plant, No. 2 unit, May 7, 1905.

No.	Time.	Revolutions per minute of engine.	Area of high-pressure card.			Mean effective pressure per square inch.		Indicated horsepower of high pressure.	Area of low-pressure card.		
			Head.	Crank.	Length.	Head.	Crank.		Head.	Crank.	Length.
			Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*		*Sq. in.*	*Sq. in.*	*Inches.*
1	2.15	163	0.43	0.41	2.86	6.0	5.7	16.9	0.10	0.11	2.82
2	2.30	166	2.78	2.82	2.85	38.9	39.5	116	1.82	1.72	2.80
3	2.45	166	2.85	2.86	2.85	39.9	40.0	118	1.61	1.69	2.80
4	3.00	166	2.98	2.89	2.87	41.4	40.2	120	1.56	1.72	2.82
5	3.15	165	2.97	2.84	2.85	41.6	39.8	119	1.74	1.79	2.80
6	3.30	165	2.91	2.78	2.85	40.7	38.9	117	1.73	1.74	2.81
7	3.45	166	2.90	2.79	2.86	40.5	38.9	117	1.64	1.73	2.80
8	4.00	165	2.95	2.84	2.85	41.3	39.8	119	1.65	1.74	2.81
9	4.15	165	2.91	2.77	2.86	40.6	38.6	116	1.66	1.75	2.82
10	4.30	165	2.78	2.81	2.85	38.9	39.3	115	1.63	1.73	2.81
11	4.45	164	2.87	2.73	2.86	40.0	38.1	114	1.64	1.74	2.81
12	5.00	164	2.86	2.80	2.86	39.9	39.1	115	1.65	1.70	2.82
13	5.15	163	2.91	2.77	2.92	39.8	37.8	112	1.66	1.71	2.84
	Mean										

No.	Time.	Mean effective pressure per square inch.		Indicated horsepower of low pressure.	Total indicated horsepower.	Mean discharge per second.	Leveled head.	Useful water horsepower.
		Head.	Crank.					
		Pounds.	*Pounds.*			*Cubic feet.*	*Feet.*	
1	2.15	0.74	0.81	6.1	23		Friction load.	
2	2.30	13.51	12.77	105	221			
3	2.45	11.95	12.55	98	216			
4	3.00	11.50	12.69	96	216			
5	3.15	12.92	13.30	104	223		9.75	
6	3.30	12.80	12.88	102	219			
7	3.45	12.18	12.85	100	217			
8	4.00	12.21	12.88	99	218			
9	4.15	12.24	12.90	100	218			
10	4.30	12.06	12.80	99	214			
11	4.45	12.14	12.88	99	213			
12	5.00	12.16	12.54	97	212		9.74	
13	5.15	12.15	12.52	97	209			
	Mean				216	87.4	9.74	96.4

Tests Nos. 33 and 34.—Plant Owned by the Riverside Highland Water Company near Colton.

Equipment.—Two cross-compound condensing Corliss steam engines; cylinders 16 and 30 by 30 inches; rods on the crank ends of both cylinders, $3\frac{1}{8}$ inches; tail rods to pumps, 2.5 inches; a single wrist plate used on each cylinder. Two sets of Babcock & Wilcox water-tube boilers, with 72 4-inch tubes, 16 feet long; built for 160 pounds pressure; Greene's fuel economizers in the stack. Duplicate sets of Snow duplex oil pumps, 4.5 by 2.75 by 4 inches, with Worthington piston meter in the oil line. Duplicate sets of Snow duplex feed pumps, 6 by 4 by 6 inches, outside packed water end, with Worthington piston meter in the feed line. Two air pumps, built by the engine manufacturers, of the plain belt and crank-driven type, belted to the main engine; cylinders 8 by 9.5 inches. Two surface condensers contained in the suction lines. Two sets of outside packed plunger pumps built by the engine manufacturers; plungers, 11 by

30 inches; rods, 2.5 inches; size of suction on each set, 18 inches; one 12 by 48 inch air chamber on each suction; suction pipe on each pump 12 inches in diameter; 11-inch discharge on each pump, and a 24-inch discharge on the whole plant. Pipe line is 24 inches in diameter and 2,500 feet long.

Steam pressure (average), 148 pounds; receiver gauge north engine, 14 pounds; receiver gauge south engine, 13 pounds; vacuum gauge north engine, 26 inches; vacuum gauge south engine, 26.5 inches; oil fed to burners under 45 pounds pressure; temperature of hot well, 90° F.; temperature beyond heater, 113° F.; temperature beyond economizer (boiler feed), 171° F.; temperature of oil feed, 135° F.

Suction lift, 4.5 feet (measured); discharge lift, 242.5 feet (measured); total lift, 247 feet. No. 61.5 spring in high-pressure indicator; No. 20.5 spring in low-pressure indicator.

Fuel.—Crude oil at $1 per barrel (nominal).

This plant is a type of the best practice in high-duty pumping engines as applied to irrigation. Though such pumps are not often used for this purpose, the plant clearly shows the great economy of fuel which can be realized in such cases. No weir was installed in this test, as the pump displacement, corrected for the slight leakage at the stuffing boxes (measured, 3 gallons per minute) and for about 2 per cent slip through the valves (a value known to be average for such a type of pump), gives, in the writer's opinion, a better measure of the discharge than a weir. The pumps take their water from a ditch and lift it over a high bluff to the upper canal above Highgrove. This plant has been designed for the highest possible economy, regardless of expense.

At the time of the test the governors on both engines were slightly out of adjustment, causing a tendency to race. For this reason the engineer did not run the north engine over 38 revolutions per minute and the south engine over 32 revolutions per minute. Since that time it is understood that the governors have been adjusted, and both pumps run up to 45 revolutions per minute. Under such conditions the plant would give a slightly better result.

Water evaporated.—Total for test (per meter), 2,858 gallons in six hours, or 476 gallons, or 3,966 pounds, per hour. Temperature of feed was 172° F. Factor of evaporation, 1.09; water evaporated per hour (equivalent) from and at 212° F., 4,320 pounds; water evaporated from and at 212° F. per indicated horsepower per hour (including auxiliaries), 19.87 pounds. Water evaporated from and at 212° F. per pound of oil, 14.45 pounds.

Log of test No. 33, Riverside Highland plant, north engine, June 24, 1905.

No.	Time.	Revolution counter.	Revolutions per minute.	Area of high-pressure card.			Mean effective pressure per square inch.		Area of low-pressure card.			Mean effective pressure per square inch.		Indicated horse-power of high pressure.	Indicated horse-power of low pressure.	Total indicated horse-power.	Discharge per second.	Measured head.	Useful water horse-power.
				Head.	Crank.	Length.	Head.	Crank.	Head.	Crank.	Length.	Head.	Crank.						
				Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*	*Sq. in.*	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*				*Cu. ft.*	*Feet.*	
1	10.35	481,378	37.3																
2	11.00	482,310	37.2	4.50	4.71	4.64	59.6	62.4	2.79	2.71	4.71	12.14	11.80	67.1	47.4	114.5	3.90		109.1
3	11.30	483,425	37.3	4.75	4.74	4.65	62.8	62.7	2.78	2.72	4.70	12.13	11.86	68.9	47.4	116.3	3.89		108.8
4	12.00	484,544	37.2	4.85	4.79	4.66	64.0	63.2	2.81	2.76	4.70	12.26	12.04	70.0	48.1	118.1	3.90		109.1
5	12.30	485,660	37.2	4.25	4.51	4.67	56.0	59.4	3.18	2.92	4.71	13.84	12.71	63.4	52.4	115.8	3.89		108.8
6	1.00	486,779	37.3	4.54	4.53	4.67	59.8	59.7	3.03	2.95	4.70	13.21	12.87	65.7	51.6	117.3	3.90		109.1
7	1.30	487,899	37.3	4.46	4.83	4.68	58.6	63.5	3.21	2.89	4.66	14.12	12.71	67.2	53.1	120.3	3.90		109.1
8	2.00	489,018	37.3														3.90		109.1
9	2.30	490,140	37.4														3.92		109.7
10	3.00	491,262	37.4	Indicators on south engine.													3.92		109.7
11	3.30	492,380	37.3														3.90		109.1
12	4.00	493,498	37.3														3.90		109.1
13	4.30	494,621	37.4														3.92		109.7
	Mean.		37.3													117.0	3.90	247	109.2

Log of test No. 34, Riverside Highland plant, south engine, June 24, 1905.

No.	Time.	Revolution counter.	Revolutions per minute.	Area of high-pressure card.			Mean effective pressure per square inch.		Area of low-pressure card.			Mean effective pressure per square inch.		Indicated horse-power of high pressure.	Indicated horse-power of low pressure.	Total indicated horse-power.	Discharge per second.	Measured head.	Useful water horse-power.
				Head.	Crank.	Length.	Head.	Crank.	Head.	Crank.	Length.	Head.	Crank.						
				Sq. in.	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*	*Sq. in.*	*Sq. in.*	*Inches.*	*Lbs.*	*Lbs.*				*Cu. ft.*	*Feet.*	
1	10.35	540,463																	
2	11.00	541,251	31.5														3.30		92.3
3	11.30	542,190	31.3														3.27		91.5
4	12.00	543,132	31.4														3.28		91.8
5	12.30	544,069	31.2	Indicators on north engine.													3.26		91.2
6	1.00	545,001	31.1														3.25		90.9
7	1.30	545,941	31.3														3.27		91.5
8	2.00	546,879	31.3	4.66	5.06	4.66	61.5	66.8	2.78	2.91	4.74	12.02	12.59	59.2	40.9	100.1	3.27		91.5
9	2.30	547,814	31.2	4.49	4.54	4.65	59.4	60.0	3.18	3.20	4.73	13.78	13.86	54.9	45.8	100.7	3.26		91.2
10	3.00	548,758	31.5	4.17	4.50	4.68	54.8	59.1	3.14	3.20	4.69	13.73	13.98	52.9	46.3	99.2	3.30		92.3
11	3.30	549,695	31.2	4.13	4.52	4.67	54.4	59.5	3.33	3.39	4.74	14.40	14.66	52.4	48.1	100.5	3.26		91.2
12	4.00	550,629	31.1	4.38	4.70	4.66	57.8	62.0	3.32	3.31	4.74	14.35	14.31	55.0	47.3	102.3	3.25		90.9
13	4.30	551,561	31.1														3.25		90.9
	Mean.		31.3													100.6	3.27	247	91.4

Test No. 36.—Air Plant of the San Dimas Irrigation Company, near San Dimas.

Equipment.—A simple noncondensing slide-valve steam engine and compressor; engine cylinder, 12 by 12 inches; rod, $1\frac{1}{2}$ inches; air cylinder in tandem on tail rod—cylinder, 14 by 12 inches; throttling governor; spring-operated valves on air cylinder; one return-tubular boiler; Deane duplex boiler feed pump, $4\frac{1}{2}$ by $2\frac{3}{4}$ by 4 inches; a feed-water heater; oil fed by gravity; $61\frac{1}{2}$-pound indicator spring on steam cylinder; 40-pound spring in indicator on air cylinder; boiler pressure, 94 pounds; air pressure in the receiver, 54 pounds; temperature of feed water, about 150° F. Weir No. 1 30-inch, rectangular, contracted; weir No. 2, 20-inch rectangular, contracted. Lift about 50 feet.

Fuel.—Crude oil of about 18° Baumé, costing 75 cents per barrel.

This test is satisfactory in every way, except as to the measurement of the lift. The accepted mean of 50 feet is little more than an estimate among a number of results by gauge and tape differing widely. The final result must then be taken for what it is worth. The total output of water by the plant is found by subtracting the discharge of weir No. 2 from that of No. 1.

Test of log No. 36, San Dimas Irrigation Company, June 17, 1905.

No.	Time.	Revolutions per minute of engine.	Area of card.			Mean effective pressure per square inch.		Indicated horse-power.	Weir No. 1.		Weir No. 2.		Measured head.	Useful water horse-power.
			Head.	Crank.	Length.	Head.	Crank.		Reading.	Discharge per second.	Reading.	Discharge per second.		
			Sq. in.	Sq. in.	In.	Lbs.	Lbs.		In.	Cu. ft.	In.	Cu. ft.	Feet.	
1	10.30	120	3.24	3.34	3.82	52.2	53.8	43.0	$4\frac{5}{8}$	1.93				
2	11.00	122	3.23	3.39	3.82	52.0	54.6	43.9	$4\frac{5}{8}$	1.93	$2\frac{3}{4}$	0.592		
3	11.30	118	3.18	3.32	3.80	51.5	53.7	41.9	$4\frac{5}{8}$	1.93				
4	12.00	122	3.19	3.26	3.82	51.4	52.5	42.7	$4\frac{5}{8}$	1.93	$2\frac{3}{4}$	.592		
5	12.30	126	3.26	3.29	3.83	52.4	52.8	44.6	$4\frac{5}{8}$	1.93				
6	1.00	126	3.25	3.36	3.82	52.3	54.1	45.1	$4\frac{5}{8}$	1.93	$2\frac{3}{4}$	.592		
7	1.30	126	3.22	3.28	3.80	52.1	53.0	44.6	$4\frac{5}{8}$	1.93				
8	2.00	129	3.16	3.25	3.81	51.0	52.5	45.0	$4\frac{5}{8}$	1.93	$2\frac{3}{4}$	.592		
9	2.30	126	3.21	3.27	3.80	52.0	52.9	44.5	$4\frac{5}{8}$	1.93				
	Mean.							43.9		1.93		.592	50	7.59
[a]10		126	3.03	3.04	3.80	31.9	32.0	37.3						

[a] Test of air cylinder.

Test No. 37.—The Del Monte Air Lift, Claremont.

Equipment.—Smith-Vaile cross-compound condensing engine; Meyer cut-off on high, plain slide on low; cylinder sizes, 12 and 18 by 18 inches; piston rods, $2\frac{1}{2}$ inches all through; 2 (duplicate set) return-tubular boilers; 2 single-stage compressors in tandem with and on tail rods of steam cylinders, 16 by 18 inches; positive admis-

sion valves, spring discharge; Smith-Vaile duplex feed pumps (duplicate set), $5\frac{1}{4}$ by $3\frac{1}{2}$ by 5 inches; Smith-Vaile air pump, 7 by 10 inches, belted and geared; also drives a plunger pump for circulation in the air jackets; condenser, consisting of a nest of 2-inch pipes in a concrete tank through which part of the discharge from the wells flows; $61\frac{1}{2}$-pound indicator spring on high-pressure cylinder; $20\frac{1}{2}$-pound indicator spring on low-pressure cylinder; 40-pound spring on air cylinder; steam pressure, 125 pounds; receiver pressure, $22\frac{1}{2}$ pounds; vacuum gauge, 22 inches; air pressure, 57 pounds. Weir No. 1, an 18-inch suppressed rectangular; weir No. 2, a 36-inch suppressed rectangular; weir No. 3, a 36-inch suppressed rectangular.

Mean lift, 88 feet (measured).

Fuel.—Crude oil, 19° Baumé, costing 75 cents per barrel.

The lift here was measured by means of a dry steel tape, which seemed to give fairly reliable results. The gauge readings at each well (corrected), the pipe lengths, and heads are given in the following table:

Gauge readings, pipe lengths, and heads in wells at Del Monte air lift.

No. of well.	Length of air pipe.	Pressure per square inch.	Head by gauge.	Measured head.	No. of well.	Length of air pipe.	Pressure per square inch.	Head by gauge.	Measured head.
	Feet.	*Pounds.*	*Feet.*	*Feet.*		*Feet.*	*Pounds.*	*Feet.*	*Feet.*
206	203	52.5	81.8	90.2	53				85.6
207	201	47.5	91.3	88.0	50	202	49.5	87.6	
208	205	49.5	90.6	86.6	52				

It will be noticed from the above that the only three wells upon which the gauge head, as well as the actual head, could be measured, were Nos. 206, 207, and 208. The mean of these three is about 88 feet by either of the two methods. Undoubtedly the method of getting the head on an air lift by means of a pressure gauge is a crude one, but it is also doubtful whether any other method is any better unless it be the method by a long rubber tube, which could not be used on any of these wells tested.

The water measurement was not entirely satisfactory. The whole output of the plant was measured on wiers Nos. 1 and 2. Weir No. 3 was inserted in the same branch as and above weir No. 1, but with the discharge from some of the wells entering between them. Above No. 3 the discharge from other air wells entered, as well as the discharge from a deep-well pump operated from another plant. The discharge from the air wells above No. 3 was estimated at 0.8 second-foot by means of a rectangular orifice. Hence the output of the air plant is obtained as follows: The discharge over weir No. 3 reduced by 0.8 second-foot is to be deducted from No. 1. This amount added to the discharge over No. 2 gives the total discharge of the plant.

Mechanical efficiency of engine and compressor is $\frac{106.9}{116.7}=91\frac{1}{2}$ per cent.

Log of test No. 37, the Del Monte air plant, June 15, 1905.

No.	Time.	Revolutions per minute of engine.	Area of high-pressure card.			Mean effective pressure per square inch.		Indicated horse-power of high pressure.	Area of low-pressure card.			Mean effective pressure per square inch.	
			Head.	Crank.	Length.	Head.	Crank.		Head.	Crank.	Length.	Head.	Crank.
			Sq. ins.	*Sq. ins.*	*Ins.*	*Lbs.*	*Lbs.*		*Sq. ins.*	*Sq. ins.*	*Ins.*	*Lbs.*	*Lbs.*
1	10.00	93	2.63	2.95	2.82	57.4	64.3	55.7	3.47	3.52	2.79	25.5	25.9
2	10.30	105	2.66	2.97	2.82	58.0	64.8	63.4	2.97	3.28	2.79	21.8	24.1
3	11.00	98	2.63	2.96	2.83	57.2	64.3	58.6	2.92	3.34	2.80	21.4	24.5
4	11.30	92	2.64	2.98	2.82	57.6	65.0	55.5	3.18	3.34	2.79	23.4	24.5
5	12.00	107	2.63	2.95	2.82	57.4	64.3	64.1	3.18	3.33	2.79	23.4	24.5
6	12.30	106	2.60	2.96	2.83	56.5	64.3	63.0	3.03	3.30	2.80	22.2	24.2
7	1.00	105	2.62	2.95	2.83	56.9	64.1	62.5	3.35	3.31	2.80	24.5	24.2
8	1.30	104	2.57	2.93	2.83	55.8	63.7	61.1	3.04	3.27	2.79	22.3	24.0
9	2.00	100	2.58	2.92	2.82	56.2	63.7	59.0	3.24	3.31	2.79	23.8	24.3
10	2.30	111	2.63	2.96	2.83	57.2	64.3	66.3	3.35	3.41	2.80	24.5	25.0
11	3.00	102	2.61	2.96	2.82	56.9	64.6	61.0	3.26	3.29	2.79	24.0	24.2
12	3.30	108	2.60	2.85	2.83	56.5	61.9	62.9	2.73	3.16	2.77	20.2	23.4
13	4.00	109	2.61	2.91	2.84	56.5	63.0	64.1	3.06	3.23	2.79	22.5	23.7
	Mean												
14[a]	4.10	109	1.94	1.85	2.78	27.9	26.6	53.6	1.95	1.80	2.77	28.2	26.0

No.	Time.	Indicated horse-power of low pressure.	Total indicated horse-power.	Weir No. 1.		Weir No. 2.		Weir No. 3.		Mean head.	Useful water horse-power.
				Readings.	Discharge per second.	Readings.	Discharge per second.	Readings.	Discharge per second.		
				Inches.	*Cu. ft.*	*Inches.*	*Cu. ft.*	*Inches.*	*Cu. ft.*	*Feet.*	
1	10.00	54.2	109.9	$3\frac{3}{8}$	0.746	$3\frac{1}{4}$	1.408				
2	10.30	54.7	118.1	$3\frac{1}{2}$	.787	$3\frac{1}{4}$	1.408				
3	11.00	51.0	109.6	$3\frac{3}{8}$	.746	$3\frac{1}{4}$	1.408				
4	11.30	50.0	105.5	$3\frac{7}{16}$	.766	$3\frac{5}{16}$	1.449	$2\frac{1}{2}$	0.950		
5	12.00	58.1	122.2	$3\frac{7}{16}$	.766	$3\frac{5}{16}$	1.449				
6	12.30	55.8	118.8	$3\frac{3}{8}$	.746	$3\frac{7}{16}$	1.533				
7	1.00	58.0	120.5	$3\frac{1}{4}$	.704	$3\frac{3}{16}$	1.367				
8	1.30	54.6	115.7	$3\frac{5}{16}$	.725	$3\frac{7}{16}$	1.533				
9	2.00	54.6	113.6	$3\frac{3}{16}$	.683	$3\frac{5}{16}$	1.449	$2\frac{13}{32}$	.896		
10	2.30	62.3	128.6	$3\frac{1}{4}$	.704	$3\frac{9}{16}$	1.615				
11	3.00	56.0	117.3	$3\frac{3}{8}$	.746	$3\frac{1}{2}$	1.574				
12	3.30	53.4	116.3	$3\frac{3}{8}$	.746	$3\frac{1}{2}$	1.574				
13	4.00	57.1	121.2	$3\frac{3}{8}$	.746	$3\frac{1}{2}$	1.574				
	Mean		116.7		.739		1.488		.923	87.4	20.8
14[a]	4.10	53.3	106.9								

[a] Test on air cylinder.

Test No. 38.—Air Lift of the Irrigation Company of Pomona.

Equipment. A cross-compound condensing Corliss steam engine; cylinders 13 and 26 by 24 inches; rods, $2\frac{1}{4}$ inches on high pressure and $3\frac{3}{4}$ inches on low pressure; single wrist plate on high, and double on low pressure; speed about 73 revolutions per minute; fly wheel 10 feet in diameter, 25 inches face, $2\frac{1}{4}$ inches thickness of rim; two return-tubular boilers (duplicate set) with 6 by 16 feet shells; oil burners draw fuel by suction; 2 single-stage air compressors in tandem with

the steam cylinders; size of air cylinders 17 by 24 inches, with $2\frac{3}{8}$-inch rods on both sides; direct-driven admission valves, spring discharge valves; Wainwright surface condenser; Deane air and circulating pumps combined; Snow duplex boiler feed pump; No. $1\frac{1}{2}$ centrifugal pump for water circulation in air jackets; $61\frac{1}{2}$-pound indicator spring on high-pressure cylinder; $20\frac{1}{2}$-pound indicator spring on low-pressure cylinder; 40-pound spring on air cylinder; steam pressure (average), 140 pounds; receiver pressure (average), 19 pounds; vacuum gauge (average), 25 inches; air pressure, 56 pounds.

Mean lift, about 42 feet.

East weir, a 48-inch suppressed rectangular; west weir, a 30-inch suppressed rectangular.

Fuel.—Crude oil, 17° Baumé, at 75 cents per barrel.

The plant is typical of many of the large air lifts found in southern California. Though of low efficiency, the air lift possesses the advantage of carrying all its machinery on the surface and within the powerhouse. It was found practically impossible to measure the depth from the surface to the water in the 12 wells which were being pumped at the time of the test. The rubber tube and dry string were both tried without success. The head, therefore, was assumed as that computed from the known air pressure at the wells and the length of the air pipe. The truth of this assumption was afterwards checked in the case of the Del Monte air plant, where the depth to water was successfully measured on a dry steel tape. The assumed value, 42 feet, is liable to an error of perhaps 10 per cent.

$$\text{Mechanical efficiency of compressors} = \frac{104.2}{133.7} = 78 \text{ per cent.}$$

Log of test No. 38, Irrigation Company of Pomona, June 6, 1905.

No.	Time.	Revolutions per minute of engine.	Area of high-pressure card.			Mean effective pressure per square inch.		Area of low-pressure card.			Mean effective pressure per square inch.	
			Head.	Crank.	Length.	Head.	Crank.	Head.	Crank.	Length.	Head.	Crank.
			Sq. in.	*Sq. in.*	*Inches.*	*Pounds*	*Pounds*	*Sq. in.*	*Sq. in.*	*Inches.*	*Pounds*	*Pounds*
1	10.00	73.5	4.30	2.07	3.76	70.4	33.9	2.89	2.81	3.69	16.05	15.61
2	10.30	73.0	4.42	2.13	3.75	72.5	34.9	2.83	2.81	3.69	15.72	15.61
3	11.00	73.5	4.45	2.10	3.75	73.0	34.4	2.90	2.84	3.69	16.10	15.77
4	11.30	73.0	4.39	2.09	3.76	71.8	34.2	2.84	2.78	3.70	15.73	15.40
5	12.00	73.0	4.32	2.10	3.77	70.4	34.2	2.91	2.84	3.69	16.15	15.77
6	12.30	73.0	4.39	2.03	3.76	71.8	33.2	2.78	2.81	3.70	15.40	15.57
7	1.00	73.5	4.32	2.14	3.76	70.7	35.0	2.78	2.78	3.70	15.40	15.40
8	1.30	73.5	4.34	2.14	3.76	71.0	35.0	2.81	2.76	3.70	15.57	15.30
9	2.00	73.0	4.28	2.13	3.76	70.0	34.8	2.78	2.75	3.70	15.40	15.24
10	2.30	73.0	4.25	2.07	3.75	69.7	33.9	2.75	2.73	3.70	15.24	15.13
11	3.00	73.5	4.23	2.14	3.76	69.2	35.0	2.75	2.73	3.70	15.24	15.13
12	3.30	73.0	4.28	2.10	3.75	70.2	34.4	2.75	2.74	3.70	15.24	15.18
13	4.00	73.5	4.34	2.10	3.76	71.0	34.4	2.74	2.74	3.69	15.22	15.22
14[a]	4.20	73.2	2.45	2.49	3.76	26.1	26.5	2.34	2.52	3.68	25.40	27.40

Log of test No. 38, Irrigation Company of Pomona, June 6, 1905—Continued.

No.	Time.	Indicated horse power of high pressure.	Indicated horse power of low pressure.	Total indicated horse-power.	East weir. Reading.	East weir. Discharge per second.	West weir. Reading.	West weir. Discharge per second.	Mean measured head.	Useful water horse-power.
					Inches.	*Cu. ft.*	*Inches.*	*Cu. ft.*	*Feet.*	
1	10.00........	60.9	74.3	135.2	$5\frac{1}{16}$	3.65	$3\frac{1}{2}$	1.31	....	....
2	10.30........	62.2	73.1	135.3	$5\frac{1}{4}$	3.85	$2\frac{1}{3}$	.62	....	....
3	11.00........	62.6	74.8	137.4	$5\frac{7}{32}$	3.82	$3\frac{3}{16}$	1.14	....	....
4	11.30........	61.4	72.6	134.0	$5\frac{3}{32}$	3.68	....	....	....	....
5	12.00........	60.6	74.4	135.0	$5\frac{3}{32}$	3.68	$3\frac{3}{16}$	1.14	....	....
6	12.30........	60.9	72.2	133.1	5	3.58	....	....	....	....
7	1.00........	61.7	72.3	134.0	$4\frac{3}{32}$	3.55	....	....	....	....
8	1.30........	61.8	72.4	134.2	$4\frac{15}{16}$	3.51	$3\frac{1}{8}$	1.11	....	....
9	2.00........	60.8	71.4	132.2	$4\frac{7}{8}$	3.45	....	....	....	....
10	2.30........	60.6	70.8	131.4	$4\frac{7}{8}$	3.45	$3\frac{1}{16}$	1.07	....	....
11	3.00........	60.8	71.2	132.0	$4\frac{3}{4}$	3.32	....	....	....	....
12	3.30........	60.6	71.0	131.6	$4\frac{13}{16}$	3.38	....	....	....	....
13	4.00........	61.5	71.4	132.9	$4\frac{13}{16}$	3.38	3	1.04	....	....
	Mean........	....	....	133.7	....	3.56	....	1.06	42	22
14[a]	4.20........	52.0	52.2	104.2	....	....	....	....	....	....

[a] Test on air cylinders.

SUMMARY OF COMPLETE TESTS.

The tables below summarize the results of the tests described above. For the gasoline-engine and steam-engine driven plants the *plant efficiency* is the ratio of the useful water horsepower to the indicated horsepower. For the electrically driven plants, the *plant efficiency* is the ratio of the useful horsepower to the electrical horsepower.

The final relation of fuel consumption to water lifted is expressed as the number of gallons of oil or the number of kilowatt hours required per useful water horsepower hour. In reducing this to actual cost the price paid by the pump owner per gallon of gasoline per barrel of crude oil or per kilowatt hour has been used. The number of hours which each plant runs per year, the cost of the plant, and the cost of attendance and repairs have each been obtained as accurately as possible. From the nature of the case these items are somewhat uncertain. The rate of depreciation of pumping plants varies through an enormous range, being determined largely by the skill and care of the attendant. Many plants are not insured at all. Averaging all conditions found, the following appears to be a fair estimate of the rates suitable for use in computing the fixed charges of the various types of plants.

BASIS FOR COMPUTING FIXED CHARGES.

Gasoline engine plants.

	Per cent.
Depreciation..	12 to 15
Interest..	6
Taxes and insurance.......................................	1
Average total...	20

Motor-driven plants.

	Per cent.
Depreciation	7 to 9
Interest	6
Taxes and insurance	1
Average total	15

Steam plants of ordinary type.

Depreciation	9 to 11
Interest	6
Taxes and insurance	1
Average total	17
Highest quality steam plants—average	12

In the case of the larger steam plants that per cent has been chosen for each individual case which seemed suitable to the special conditions of the plant. These percentages are applied to the first cost of the entire pumping station, including the cost of wells. The latter of course varies greatly with the depth of the wells.

The item of labor is also a difficult one to estimate. Some plants employ an engineer during the whole year, and others only during the pumping season. Others have one man to look after several plants and many plants have no attention whatever.

GASOLINE PLANTS.

The following table summarizes the results of the test of pumping plants using gasoline engines:

Summary of complete tests on gasoline pumping plants.

No. of test.	Discharge.		Lift.	Useful water horse-power.	Indicated horse-power.	Plant efficiency.	Duration of test.		Gasoline consumed.				Number of hours plant runs per year.	Total gasoline used per year.	Cost of gasoline per gallon.
	Per second.	Per minute.							Total during test.	Per hour.	Per indicated horsepower hour	Per useful water horsepower hour.			
	Cu.ft.	*Galls.*	*Feet.*			*P. ct.*	*h.*	*m.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*		*Galls.*	
1	0.328	147	44.4	1.65	5.64	29	1	7	0.97	0.87	0.154	0.527	300	261	$0.05½
2	.671	301	61.9	4.70	16.3	29	3	10	7.29	2.30	.141	.489	2,600	6,000	.05½
3	5.94	2,666	11.3	7.60	38.0	20	3	0	16.88	5.62	.148	.741	4,320	24,300	.05
4	.829	372	96.5	9.05	26.5	34	3	8½	9.28	2.95	.111	.326	496	1,460	.06
5	1.36	611	67.9	10.4	35.2	30	3	0	11.42	3.81	.108	.366	470	1,800	.05½
6	1.51	678	62.0	10.6	29.3	36	1	0	2.47	2.47	.084	.233	850	2,100	.06¾
7	1.09	489	93.5	11.4	26.7	43	4	0	11.04	2.76	.103	.242	1,800	4,970	.05¼
8	1.33	597	90.3	13.6	40.8	33	3	30	14.86	4.25	.104	.312	1,000	4,250	.05
9	4.96	2,226	55.0	30.9	63.1	49	6	0	37.85	6.31	.100	.204	1,920	12,100	.05½
10	.241	108	203.5	5.56	16.7	33	2	40	4.36	1.63	.098	.293	720	1,170	.05½
11	.354	159	180.3	7.23	13.9	52	4	41	7.70	1.64	.118	.227	360	590	.06

Summary of complete tests on gasoline pumping plants—Continued.

No. of test.	Total cost of plant.	Fixed charge per year at 20 per cent on total cost of plant.	Cost of gasoline per year.	Cost of attendance and repairs per year.	Total cost per year.	Cost per useful water horsepower hour. Fixed charges.	Cost per useful water horsepower hour. Gasoline.	Cost per useful water horsepower hour. Attendance and repair.	Cost per useful water horsepower hour. Total.	Cost per foot acre-foot. Gasoline.	Cost per foot acre-foot. Total.	Cost per acre-foot of water pumped. Gasoline.	Cost per acre-foot of water pumped. Total.
1	$3,056	$611	$14	$50	$675	$1.234	$0.029	$0.101	$1.364	$0.040	$1.875	$1.78	$83.03
2	1,400	280	330	0	610	.023	.027	.000	.050	.037	.069	2.29	4.27
3	3,400	680	1,210	300	2,190	.021	.037	.009	.067	.051	.092	.58	1.05
4	3,200	640	88	83	811	.143	.020	.018	.181	.028	.249	2.70	24.00
5	3,343	668	99	0	767	.137	.020	.000	.157	.028	.216	1.90	14.70
6	2,500	500	142	0	642	.055	.016	.000	.071	.022	.098	1.36	6.08
7	3,200	640	261	450	1,351	.031	.013	.022	.066	.018	.090	1.68	8.41
8	3,000	600	212	125	937	.044	.016	.009	.069	.022	.095	1.99	8.58
9	3,500	700	660	300	1,660	.012	.011	.005	.028	.015	.038	.82	2.09
10	3,000	600	65	0	665	.150	.016	.000	.166	.022	.228	4.48	46.40
11	1,555	311	35	75	421	.119	.014	.029	.162	.019	.223	3.43	40.20

Tests numbered 1 to 9 are of gasoline engines running centrifugal pumps. They are arranged in order of the amount of the useful water horsepower, beginning with the smallest. Tests 10 and 11 are of gasoline engines running deep-well pumps. For the centrifugal pumps the discharge varies between 0.328 cubic foot per second, or 147 gallons per minute, for No. 1, and 5.94 cubic feet per second, or 2,666 gallons per minute, for No. 3. The lift varies from 11.3 feet for No. 3 to 96.5 feet for No. 4. The pumps of Nos. 4, 7, and 8 are all compound centrifugals with lifts exceeding 90 feet, while all the others are single-runner pumps. The useful water horsepower varies from 1.65 for No. 1 to 30.9 for No. 9. The indicated horsepower varies from 5.64 for No. 1 to 63.1 for No. 9. This covers a wide range and includes within its limits the majority of pumping plants in use for irrigation in California.

The plant efficiency varies irregularly. It depends somewhat upon the condition of the gasoline engine, but probably chiefly upon the arrangement and condition of the pump and piping. All turns and obstructions in the piping, any variation in speed of the pump from the speed most suitable to the discharge and lift, any great length of discharge pipe, all tend to reduce seriously the plant efficiency. To secure the best results the size and speed of both pump and engine and all the connections and piping should be carefuly planned for the special conditions under which the plant is to operate. No. 3 has an abnormally low efficiency. As explained in the account of the test, this seems to be largely due to the low head under which the plant is operating, since it is adapted to work on a much higher head. The efficiency of No. 5 is unduly low on account of air drawn into the suction pipe. Likewise the efficiency of No. 8 is lower than would be expected in a plant of its size, but the reason is not apparent from the data obtained. In general the results indicate that the

plant efficiency should vary from about 30 per cent for the smaller plants to about 50 per cent for the largest plants. Any unusual low value means a continual loss to the owner of the plant during its operation, due either to its careless handling or to its faulty design and construction.

The amount of gasoline used per indicated horsepower hour varies rather regularly from 0.154 gallon for the smallest plant to 0.100 gallon for the largest. The amount of gasoline used per indicated horsepower hour and per useful water horsepower hour for the different plants is platted on figure 3. The amount of gasoline used per useful water horsepower hour depends upon both the plant efficiency and the amount consumed per indicated horsepower hour and hence is quite variable. For No. 3 the amount of gasoline consumed per useful horsepower hour is unduly high on account of the low plant efficiency. Omitting this plant from consideration we may con-

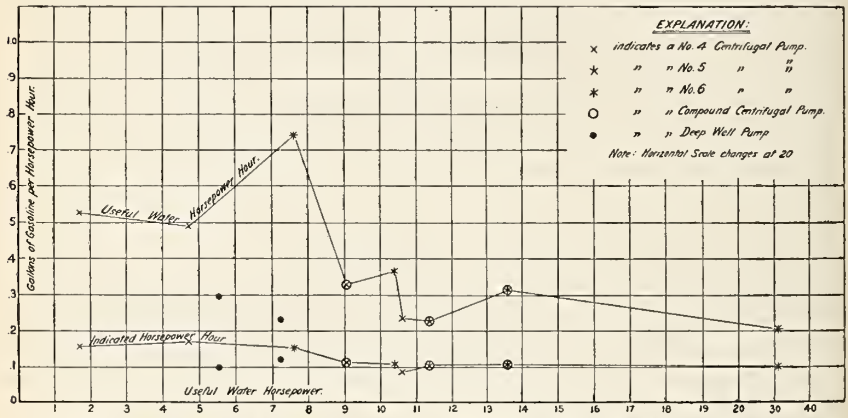

Fig. 3.—Diagram showing gasoline used per indicated and per useful water horsepower hour.

clude that the amount of gasoline required per useful horsepower hour varies from about 0.5 gallon for the smallest plant to 0.2 gallon for the largest plants.

The plant efficiency in deep-well pumps in general may probably be expected to surpass the efficiency of centrifugal pumps although the two tests, Nos. 10 and 11 in this series, are scarcely sufficient to prove the general law. The efficiency and amount of gasoline consumed in these two tests compare very favorably with the results obtained from centrifugal pumps of much larger capacity, and this fact tends to compensate in some measure for some of the disadvantages attendant upon the use of deep-well pumps.

The price of gasoline has been remarkably low ($7\frac{1}{2}$ cents per gallon) in southern California, because of the fierce competition of oil producers and refiners in that region.[a]

[a] Report on Transportation of Petroleum, Bureau of Corporations, Department of Commerce and Labor, p. 426.

In other pumping localities 10 to 12 cents a gallon is considered a low price for gasoline, and it is doubtful if the present low price will be long maintained in southern California.

On account of the great cost of wells, the total cost of plant bears no direct relation to the capacity of the pumping plant.

In many cases the charge for attendance and repairs on gasoline engines is merely nominal, but when there is a charge for attendance it is of considerable importance in comparison with the cost of gasoline. In nearly all the tests reported above the annual fixed charges for interest, depreciation, and taxes, computed at 20 per cent on the total first cost of the plant, far exceed the cost of gasoline, attendance, and repairs per year. This relation evidently depends upon the number of hours the pump runs per year. Since in many cases the pumps are used to supplement natural stream flow, the amount of use of the pumps fluctuates from year to year. Hence the interest on the pumping plant is in the nature of insurance on the crop, and it is scarcely fair to charge this item in its entirety as cost of pumping.

The cost has been reduced for purposes of comparison to cost per useful horsepower hour under the items fixed charges, gasoline consumed, attendance and repairs, and total, and to cost per foot-acre-foot under the items gasoline consumed, and total. The latter are obtained from the corresponding items under the cost per useful water horsepower hour by multiplying by $1\frac{1}{8}$. The last columns of the table give the cost per acre-foot of the water actually pumped under the headings for gasoline consumed and total. These are obtained from the preceding columns by multiplying in each case by the lift. These results are interesting as showing what it is actually costing irrigators in southern California to pump water.

ELECTRICALLY DRIVEN PUMPS.

Tests numbered 12 to 24 are for electrically operated pumps. Nos. 12 to 18 are centrifugal pumps arranged in order of useful water horsepower output, No. 19 is a screw pump, Nos. 20 and 21 are deep-well pumps, No. 22 is a triplex pump, and Nos. 23 and 24 are two tests on the same rotary pump. The electrically operated pumps tested had approximately the same range in size as the pumps run by gasoline engines. The results are summarized on the following page.

Summary of complete tests on electrically driven pumping plants.

No. of test.	Discharge. Per second.	Discharge. Per minute.	Lift.	Useful water horsepower.	Electrical horsepower.	Plant efficiency.	Duration of test.		Kilowatts.	Kilowatts per useful horsepower.	Number of hours plant runs per year.	Total kilowatt hours per year.	Cost of electricity per kilowatt hour.
	Cu. ft.	*Galls.*	*Feet.*			*Per ct.*	*h.*	*m.*					
12	0.714	320	62.0	5.01	14.5	35	2	0	10.8	2.16	2,600	28,100	\$0.02$\frac{1}{3}$
13	2.21	992	22.5	5.62	12.6	45	1	30	9.40	1.67	4,320	40.600	.02
14	1.26	566	60.3	8.57	22.0	39	2	30	16.48	1.91	1,440	23,600	.02$\frac{1}{2}$
15	2.97	1,333	28.1	9.45	55.2	17	2	0	41.2	4.36	2,880	118,700	.018
16	1.38	620	94.3	14.7	31.9	46	3	0	23.8	1.62	....	....	.02$\frac{1}{3}$
17	1.10	494	122.4	15.3	31.6	48	4	0	23.6	1.54	558	13,200	.02$\frac{1}{2}$
18	1.82	817	188.9	39.0	71.2	55	3	0	53.1	1.36	3,000	160,000	.02$\frac{1}{2}$
19	.492	221	38.2	2.13	7.16	30	1	0	5.34	2.51	1,100	5,870	.02
20	.432	194	63.0	3.08	8.42	37	2	0	6.28	2.04	2,160	13,600	.02$\frac{1}{2}$
21	.750	337	63.0	5.36	13.1	41	2	15	9.76	1.82	2,160	21,100	.02$\frac{1}{2}$
22	.691	310	75.0	5.87	11.1	53	2	15	8.29	1.41	1,440	11,900	.018
23	.742	333	88.8	7.46	13.7	54	1	0	10.29	1.37	....	....	.02
24	.679	305	98.1	7.55	15.4	49		45	11.50	1.52	1,400	16,100	.02

No. of test.	Total cost of plant.	Fixed charges per year at 15 per cent on total cost of plant.	Cost of electricity per year.	Cost of attendance and repairs per year.	Total cost per year.	Cost per useful water horsepower hour. Fixed charges.	Cost per useful water horsepower hour. Electricity.	Cost per useful water horsepower hour. Attendance and repairs.	Cost per useful water horsepower hour. Total.	Cost per foot-acre-foot. Electricity.	Cost per foot-acre-foot. Total.	Cost per acre-foot of water pumped. Electricity.	Cost per acre-foot of water pumped. Total.
12	\$1,150	\$173	\$657	0	\$830	\$0.013	\$0.050	\$0.00	\$0.064	\$0.069	\$0.088	\$4.28	\$5.46
13	2.500	375	810	\$350	1,535	.015	.033	.015	.063	.045	.087	1.01	1.96
14	1,600	240	590	223	1,053	.019	.048	.018	.085	.066	.117	3.98	7.06
15	3,000	450	2,130	500	3,080	.017	.078	.018	.113	.107	.155	3.01	4.36
16	....	....	....	....	....	....	.038	....	....	.052	....	4.90	....
17	3,400	510	330	132	972	.060	.039	.015	.114	.054	.157	6.61	19.20
18	6,000	900	4,000	1,200	6,100	.008	.034	.010	.052	.047	.071	8.88	13.40
19	1,500	225	117	0	342	.096	.050	.0	.146	.069	.201	2.64	7.68
20	3,580	540	340	150	1,030	.081	.051	.023	.155	.070	.213	4.41	13.40
21	4,950	740	530	150	1,420	.064	.046	.013	.123	.063	.169	3.97	10.60
22	3,000	450	214	100	764	.053	.025	.012	.090	.034	.124	2.55	9.30
23	....	....	....	....	....	....	.027	....	....	.037	....	3.29	....
24	2,000	300	322	0	622	.029	.030	.0	.059	.041	.081	4.02	7.95

As a rule, the plant efficiency for the electrical pump is definitely higher than for a corresponding plant operated by gasoline. This is probably largely due to the fact that less energy is absorbed in the motor than in a gasoline engine. There is less variation in efficiency due to size of plant for an electrically operated plant than for a gasoline plant. In test No. 15 the efficiency was abnormally low. The motor was running hot and the pump likewise seemed to be working badly, but it was not possible to tell by external inspection the reasons for the very poor performance of this plant. In tests Nos. 15, 16, 17, and 18 the pumps were compound centrifugals, a comparison of the efficiencies of which indicates that compound pumps are not necessarily any less efficient than single-stage pumps. Omitting from consideration No. 15, we may conclude that the plant efficiency of electrically operated pumps should at least be as good as 40 per cent for a pump of 5 useful water horsepower capacity, increas-

ing to 55 per cent for a pump with capacity of 40 useful water horsepower.

As compared with centrifugal pumps, test No. 19 shows the screw pump to be less efficient; tests 20 and 21 show the deep-well pumps to have about an equal efficiency; tests 22, 23, and 24 show the triplex and rotary pumps to have somewhat higher efficiencies, but no very conclusive statements can be based on so few tests.

The table shows that under the best conditions the smallest plants require about 1.6 kilowatts per useful water horsepower and the largest about 1.4 kilowatts.

STEAM-DRIVEN PLANTS.

Tests numbered 25 to 38 are of steam-driven pumping plants. Nos. 25 to 32 have centrifugal pumps, Nos. 33 and 34 are plunger pumps, and Nos. 36, 37, and 38 are air-lift pumping plants. Test No. 30 is based on Nos. 28 and 29, running simultaneously, and similarly No. 35 consists of Nos. 33 and 34 running together. All these plants burn crude oil as fuel. The largest ones are very much larger than any of the gasoline or electric plants tested, and hence not strictly comparable with them. A summary of these tests follows:

Summary of complete tests on steam-driven pumping plants.

No. of test.	Discharge— Per second.	Discharge— Per minute.	Lift.	Useful water horsepower.	Indicated horsepower.	Plant efficiency.	Duration of test.		Fuel oil consumed. Total during test.	Fuel oil consumed. Per hour.	Fuel oil consumed. Per indicated horsepower hour.	Fuel oil consumed. Per useful water horsepower hour.	Number of hours plant runs per year.	Total fuel oil consumed per year.	Cost of fuel oil per barrel.
	Cu. ft.	*Galls.*	*Feet.*			*P. ct.*	*H.*	*M.*	*Galls.*	*Galls.*	*Galls.*	*Galls.*		*Bbls.*	
25	.578	259	164.0	10.7	31.8	34	4	30	122.8	27.3	0.859	2.55	......	......	$0.75
26	1.37	615	94.3	14.7	31.7	46	3	0	63.9	21.3	.672	1.45	......	......	.75
27	1.71	768	213.4	41.3	107.8	38	5	30	185	33.6	.312	.814	4,320	3.460	.80
28	54.77	24,590	13.48	83.7	139	60	3	30	186.4	53.2	.383	6.36	......	......	.85
29	52.02	23,350	13.39	78.9	134	59	2	30	109.5	43.8	.327	.555	......	......	.85
30	103.7	46,550	13.59	159.6	......	......	1	30	115.2	76.8	......	.481	2,310	4,225	.85
31	95.4	42,820	9.85	106.4	239	45	3	30	187.5	53.6	.224	.594	......	4,000	.90
32	87.4	39,230	9.74	96.4	216	45	3	15	172.5	53.1	.246	.551	......		
33	3.90	1,750	247	109.2	117.0	93	......		......	......	......	......	......	......	......
34	3.27	1,468	247	91.4	100.6	91	......		......	......	......	......	......	......	......
35	......	......	......	200.6	217.6	92	6	0	229	38.2	.176	.190	5,000	4,600	1.00
36	1.34	602	50	7.59	43.9	17	4	12½	84	20.0	.456	2.64	5,800	2,700	.75
37	2.104	944	87.4	20.8	116.7	18	6	0	160	26.7	.229	1.28	[a] 3,840	2,440	.75
38	4.62	2,074	42	22.0	133.7	16	6	51	84.8	27.0	.202	1.23	5,000	3,200	.75

[a] 1905.

Summary of complete tests on steam-driven pumping plants—Continued.

No. of test.	Total cost of plant.	Rate for computing fixed charges.	Fixed charges per year.	Cost of fuel oil per year.	Cost of attendance and repairs per year.	Total cost per year.	Cost per useful water horsepower hour.				Cost per foot acre-foot.		Cost per acre-foot of water pumped.	
							Fixed charges.	Fuel oil.	Attendance and repairs.	Total.	Fuel oil.	Total.	Fuel oil.	Total.
		P. ct.												
25	......	......				......	......	$0.046	......	......	$0.063	......	$10.30	.....
26	......	......	......	......	......	......	......	.026	......	......	.036	......	3.40	.....
27	$10,000	16	$1,600	$2,760	$1,650	$6,010	$0.009	.015	$0.009	$0.033	.021	$0.045	4.48	$9.60
28	......	......	......	......	......	......	......	.013	......	......	.018			
29	......	......	......	......	......	......	......	.011	......	......	.015	......	......	.....
30	33,111	14	4,604	3,590	1,860	10,090	.012	.010	.005	.027	.014	.037	.19	.50
31, 32	50,000	14	7,040	3,600	2,100	12,700	.022	.011 / .012	.007	.040	.015	.055	.15	.54
33	......	......	......	......	......	......	......	......	......	......	......	......	......	.....
34	......	......	......	......	......	......	......	......	......	......	......	......	......	.....
35	55,000	12	6,600	4,600	2,320	13,520	.007	.005	.002	.014	.007	.019	1.73	4.69
36	5,000	17	850	2,000	1,500	4,350	.019	.045	.034	.098	.062	.135	3.10	6.50
37	7,500	17	1,275	1,830	1,800	4,905	.016	.023	.022	.061	.032	.084	2.80	7.34
38	35,000	15	5,250	2,400	1,575	9,225	.048	.022	.014	.084	.030	.116	1.26	4.87

For the plants using centrifugal pumps the plant efficiency does not seem to differ definitely from the efficiency for gasoline or electric plants. The plant efficiency of the plunger pumps is much higher than for any other type, while for the air-lift plants it is very much lower. The plant efficiencies of all the tests for the gasoline, electric, and steam plants are platted on figure 4.

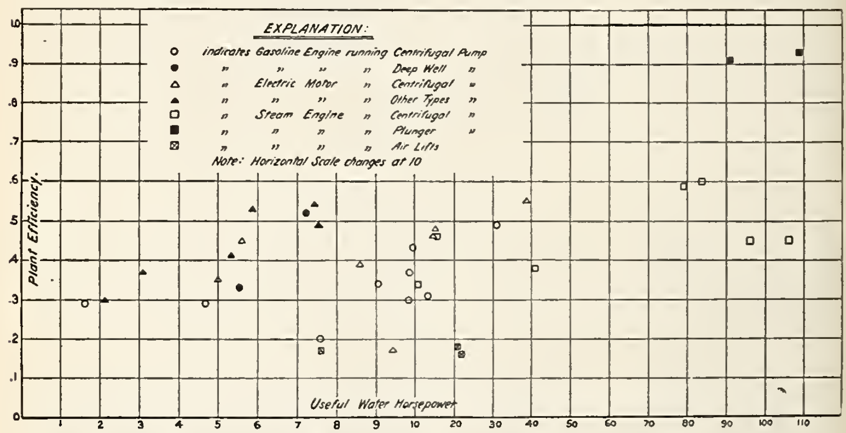

FIG. 4.—Diagram showing plant efficiency for all plants for which complete tests were made.

The amount of crude oil consumed varies from over 0.8 gallon per indicated horsepower hour for the smallest plant to a little over 0.2 gallon for the largest plants. For those using centrifugal pumps the amount of crude oil used per useful water horsepower hour varies from 2.5 gallons for the smallest plant to about 0.5 gallon for the most economical plants. A comparison with gasoline engines of cor-

responding size shows that at least four times as much crude oil is required when burned under a steam boiler as is needed of gasoline when used in an internal-combustion engine. When steam plants run intermittently, considerable fuel is required in getting up steam preparatory to starting the plant, so it is probable that in such cases the actual performance of the plants required more fuel in proportion to the work done than is shown in the tests.

A comparison of the results obtained with centrifugal pumps using gasoline, electricity, and steam as motive power shows that, at the prevailing prices, to raise 1 acre-foot of water 1 foot the cost of gasoline varies from $1\frac{1}{2}$ to 5 cents, the cost of electricity varies from $4\frac{1}{2}$ to 10 cents, and the cost of crude oil for generating steam varies from $1\frac{1}{2}$ cents upward. The total cost, according to the rates used for fixed charges and the figures obtained for attendance and maintenance, of raising 1 acre-foot of water 1 foot for gasoline plants varies from 4 cents upward, for electric plants it varies from 7 to 16 cents, and for steam plants it varies from 4 cents upward.

Tests 2 and 12 afford a direct comparison of the use of gasoline and electricity. The pump and piping were the same in the two tests, but the speed of the pump was slightly higher when run by the electric motor, resulting in an increased discharge from the pump. This would be a possible source of discrepancy in the results. The figures show for this plant the cost of gasoline to raise 1 acre-foot of water 1 foot high to be 3.7 cents, and the cost of electricity to be 6.9 cents; while the total cost for the gasoline plant is 6.9 cents and for the electric plant 8.8 cents per foot-acre-foot.

Tests 16 and 26 afford a direct comparison of the use of electricity and steam. The two tests were made in succession on the same plant under identical conditions. The results show the cost of electricity per foot-acre-foot of water pumped to be 5.2 cents and the cost of crude oil for producing steam to be 3.6 cents.

Tests 23 and 24 were carried out on the same plant. In No. 23 the plant was working under favorable conditions. In No. 24 the pump was sucking air on account of a deficient supply of water. The results show that in this case having the pump too large for the water supply increases by about 10 per cent the charge for electricity per foot-acre-foot of water lifted.

PARTIAL FUEL TESTS.

In addition to the tests above described, fuel and water tests were made on over 100 other plants immediately about the city of Pomona.

Below are described the methods used and particular features of certain of the plants.

Oil and distillate were measured in the same way as in the complete tests, except where the method of pouring into the overflow cup

already described in test No. 6 was used. About three plants were measured per day. Oil tests were usually of one to six hours duration, except in a few cases where good records could be obtained, in which event the tests lasted several days, or even for the entire season. Water measurements were made with a weir, except in the cases of the Columbia Land and Water Company, H. A. Hillman, and George J. Wright, where a Pitot tube was employed. Three-fourths of all the water measurements were made with an 18-inch Cipolletti portable steel weir, driven into a ditch with a hand ax (fig. 5). Most of the other plants had weirs already in place. Lifts were measured very carefully, except for some deep-well pumps, where they had to be

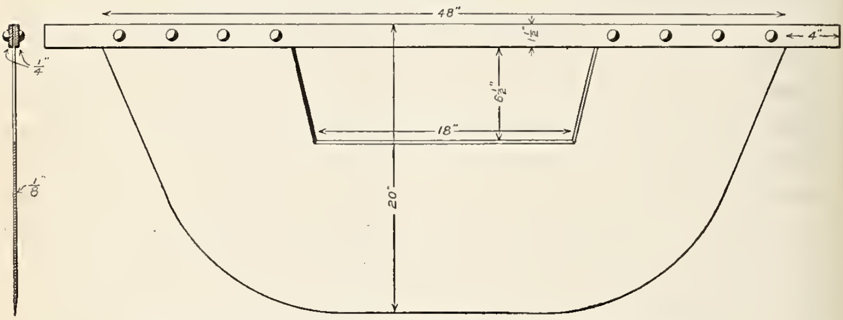

FIG. 5.—Portable steel weir used for measuring discharge of pumps.

estimated from a general knowledge of the water plane in the immediate vicinity. Suction lifts for centrifugal pumps were measured with especial care. A rubber float consisting of a bicycle tube partly filled with shot and sealed air-tight was successfully used in making these difficult measurements of the depth to water. The fuel and water measurements were not made on the same day in the cases of N. W. Miller, and the Consolidated Water Company of Pomona, No. 4.

SUMMARY OF ALL TESTS AT POMONA.

The accompanying tables give the results of all the tests made in and about Pomona, including, for purposes of comparison, the complete as well as the partial tests:

s and centrifuga

No.	ge. Cubic [f]eet pe[r] [s]econd	Suction.	Disc	L	Cost per foot-acre-foot. Gasoline.	Total.	Cost per acre-foot of water pumped. Gasoline.	Total.
		Feet.	*F*					
1	0.07	5		..	$0.228	....	$4.10	....
2	.154	16.9		..	.125	....	4.20	....
3	.259	24		5	.103	$3.580	3.10	$11.00
4	.154	19.8		..	.085	....	4.60	....
5	.463	14.3		9	.072	1.580	1.40	31.00
6	.328	12		1	.047	4.280	1.50	130.00
7	.169	29.5		5	.067	1.620	5.20	130.00
8	.323	1		5	.040	1.770	1.80	79.00
9	.67	19.4		1	.038	.153	.93	3.80
10	.330	25.5		4	.044	.377	2.40	20.00
11	.363	27.5		1	.043	.978	2.10	48.00
12	.490	22.5		1	.033	.565	1.40	25.00
13	.479	25.5		1	.074	.510	3.60	25.00
14	.47[illegible]	27		5	.070	.268	3.40	13.00
15	.57[illegible]	24		..	.065	....	3.00	....
16	.80	28		8	.034	.368	1.10	12.00
17	.53[illegible]	18		3	.040	.334	2.10	18.00
18	.59[illegible]	28		..	.034	....	1.70	....
19	.87[illegible]	19.7		1	.036	.414	1.60	19.00
20	1.32	17		..	.051	....	1.80	....
21	1.02[illegible]	23.5		6	.040	.228	2.60	11.00
22	.593	29.5		..	.033	....	3.00	....
23	.505	13		..	.021	....	2.30	....
24	1.[illegible]7[illegible]	14.3		0	.025	.412	1.00	17.00
25	.994	15.5		3	.030	.155	1.80	9.10
26	.341	29.5		6	.043	.242	7.40	42.00
27	.800	16.2		8	.026	.382	1.90	28.00
28	.481	27		30	.054	.179	6.60	22.00
29	1.314	28		4	.025	.129	1.10	5.90
30	.974	26.6		73	.018	.238	1.20	16.00
31	1.415	15		54	.025	.074	1.20	3.50
32	.890	27		8	.022	.148	1.80	12.00
33	1.183	27.7		52	.022	.072	1.30	4.40
34	1.270	22		..	.016	....	.91	....
35	1.052	23		58	.016	.080	1.20	5.80
36	.827	8		83	.028	.252	2.70	24.00
37	.887	5		...	.051	....	4.90	....
38	1.222	28.8		52	.021	.072	1.50	5.10
39	1.265	24		...	.018	....	1.20	....
40	.873	22		65	.029	.089	3.10	9.40
41	1.354	18		57	.028	.216	1.90	15.00
42	.675	17.5		...	....	....	....	....
43	.822	25		...	.030	....	3.40	....
44	1.515	21		71	.022	.098	1.40	6.10
45	1.078	19.5		66	.018	.091	1.70	8.50
46	1.092	24		13	.022	.155	2.10	15.00
47	1.319	23		69	.022	.095	2.00	8.60

Cost of pumping with gasoline engines and centrifugal pumps, Pomona, 1905.

No.	Owner.	Well. Date.	Well. Diameter.	Well. Depth.	Engine. Make.	Engine. Horsepower.	Engine. Revolutions per minute.	Pump. Make.	Pump. No.	Pump. Kind.	Pump. Revolutions per minute.	Discharge. Gallons per minute.	Discharge. Cubic feet per second.	Lift. Suction.	Lift. Discharge.	Lift. Total.	Useful water horsepower.	Gasoline. Consumed per hour.	Gasoline. Cost per gallon.	Gasoline. Cost per hour.	Gasoline. Per useful water horsepower hour.	Total hours run in 1905.	Cost of attendance per hour.	Cost of repairs, 1905.	Total cost of plant.	Cost per useful water horsepower hour. Fixed charges.	Cost per useful water horsepower hour. Gasoline.	Cost per useful water horsepower hour. Attendance and repairs.	Cost per useful water horsepower hour. Total.	Cost per foot-acre-foot. Gasoline.	Cost per foot-acre-foot. Total.	Cost per acre-foot of water pumped. Gasoline.	Cost per acre-foot of water pumped. Total.
			Inches.	Feet.										Feet.	Feet.	Feet.		Gallons.			Gallons.												
1	Moore, H. E.	Sept. 18	4	130	Stover	3	337	Livingston	1½	Single horizontal	1,403	32	0.071	5	13	18	0.145	0.35	$0.06¾	$0.024	2.414	840					$0.166			$0.228		$4.10	
2	Campbell, N. D.	Aug. 16	7		Western	8	235	Byron Jackson	4	Single vertical	593	69	.154	16.9	16.5	33.4	.583	.79	.06¾	.053	1.355	144					.091			.125		4.20	
3	Anderson, Lewis	Aug. 24	7	238	White & Middleton	11	225	do	4	Single horizontal	870	112	.250	24	6	30	.850	.92	.07	.064	1.082	100			$1,075	$2.530	.075		$2.605	.103	$3.580	3.10	$11.00
4	Moore, B. F.	Aug. 11	6	265	Dayton	8	302	Van Wie	3	Single vertical	850	69	.154	19.8	34	53.8	.938	1.05	.05½	.058	1.119	600					.062			.085		4.40	
5	Merriam, E. J.	Aug. 16	7	198	Root & Van Dervoort	5	270	Lowville	3	Single horizontal	585	208	.463	14.3	5.1	19.4	1.02	.76	.07	.053	.745	210		$25.00	1,050	.980	.052	$0.117	1.149	.072	1.580	1.40	31.00
6	Currie, M.	Sept. 11	7	333	White & Middleton	7	250	Byron Jackson	3	Single vertical	1,021	147	.328	12	19.5	31.5	1.17	.60	.06¾	.040	.513	100			1,800	3.077	.034		3.111	.047	4.280	1.50	130.00
7	Lenert, J.	do	7	270	do	11	268	do	3	do	1,451	76	.169	29.5	48	77.5	1.48	1.32	.05½	.073	.892	240			2,000	1.126	.049		1.175	.067	1.620	5.20	130.00
8	Heim, D. W.	May 29	7	286	do	11	240	do	4	do	800	147	.328	1	43.4	44.4	1.65	.87	.05½	.048	.527	300	$0.16⅔	10.00	3,156	1.235	.029	.121	1.285	.050	1.770	1.80	79.00
9	McKinley, Thos.	Aug. 16	10	200	Root & Van Dervoort	5	248	do	4	Single horizontal	942	301	.671	19.4	5.2	24.6	1.87	.76	.07	.053	.406	900			700	.083	.028		.111	.038	.153	.93	3.80
10	Hamm, H. F.	Aug. 10	7	335	White & Middleton	11	265	Krogh	3	Single vertical	1,014	148	.330	25.5	28	53.5	2.00	1.18	.05½	.065	.590	600		50.00	1,200	.200	.032	.042	.274	.044	.377	2.40	20.00
11	Desnoyers, V.	Aug. 22	9	226	Foos	10	215	Byron Jackson	3	Single horizontal	1,150	165	.368	27.5	22	49.5	2.06	.90	.07	.063	.437	200			1,400	.680	.031		.711	.043	.978	2.10	48.00
12	Welgie, Geo. J.	Aug. 8	9	275	White & Middleton	15	214	do	4	Single vertical	605	224	.499	22.5	21	43.5	2.46	1.12	.05¼	.059	.455	420			2,000	.387	.024		.411	.033	.565	1.40	25.00
13	Murdoch, M. A.	Sept. 12	7	247	Fairbanks-Morse	12	228	do	4	do	887	215	.479	25.5	23	48.5	2.63	2.02	.07	.141	.768	360			1,500	.317	.054		.371	.074	.510	3.10	25.00
14	Cunningham & Newton	Aug. 17	7	320	Stearns	12	225	do	4	do	835	214	.477	27	22	49	2.65	1.98	.06¾	.134	.747	735			1,400	.144	.051		.195	.070	.268	3.40	13.00
15	Day, E. M.	do	7	314	White & Middleton	25	203	do	5	do	755	258	.575	24	22	46	3.00	2.07	.06¾	.140	.690	768		10.00			.047	.004		.065		3.00	
16	Schaefer, W. J.	Aug. 24	7	320	do	11	245	do	5	Single horizontal	862	361	.804	28	5.5	33.5	3.05	1.12	.06¾	.076	.367	405			1,500	.243	.025		.268	.034	.368	1.10	12.00
17	Clugston, C. G.	July 20	12	65	do	25	194	do	5	Single vertical	688	241	.537	18	35	53	3.22	1.69	.05½	.093	.525	450		15.00	1,475	.204	.029	.010	.243	.040	.334	2.10	18.00
18	Robertson, B. Y.	Aug. 12	10	150	do	15	243	do	4	do	804	267	.595	28	22	50	3.37	1.24	.06¾	.084	.368	234		10.00			.025	.013		.034		1.70	
19	Hillman, G. A.	do	10	765	do	25		do	5	do		393	.876	19.7	25.5	45.2	4.49	2.20	.05¼	.115	.490	567			3,500	.275	.026		.301	.036	.414	1.10	19.00
20	Green, T. J.	Aug. 4	10		do	25	220	do	5	do	790	594	1.324	17	18.5	35.5	5.32	3.75	.05¼	.197	.705	1,040					.037			.051		1.80	
21	Chotro, Jose	Sept. 15	10	300	do	24	217	do	5	do	695	459	1.023	23.5	26	49.5	5.74	2.41	.07	.169	.420	720	.15		2,300	.111	.029	.026	.166	.040	.228	2.00	11.00
22	Jones, W. E.	Aug. 22	10	300	do	30	200	do	5	do	870	266	.593	29.5	60	89.5	6.01	2.75	.05¼	.144	.458	900					.024			.033		3.00	
23	Bosbyshell, Wm.	July 12	10	340	West Coast	25	275	do	4	Compound vertical	800	226	.504	13	96	109	6.21	1.78	.05¼	.093	.287	504					.015			.021		2.30	
24	Gustafson, V.	Aug. 12	10	640	Western	24	200	do	5	Single vertical	722	615	1.370	14.3	27	41.3	6.41	2.14	.05½	.118	.334	420			3,800	.282	.018		.300	.025	.412	1.00	17.00
25	Hume & Gallup	Aug. 8	10	378	Fairbanks-Morse	22	195	Krogh	5	do	730	446	.994	15.5	43	58.5	6.59	2.78	.05¼	.146	.422	830		15.00	2,400	.088	.022	.003	.113	.030	.155	1.80	9.10
26	Portier & Alleman	Sept. 9	10	315	Otto	38	229	Byron Jackson	4	Compound vertical	1,069	153	.341	29.5	142	171.5	6.62	3.05	.06¾	.206	.461	500			2,400	.145	.031		.176	.043	.242	7.40	42.00
27	Cobb & Landon	Aug. 11	10	400	do	21	225	do	5	Single vertical	790	359	.800	16.2	57	73.2	6.63	1.80	.07	.126	.272	411		47.70	3,500	.257	.019	.002	.278	.026	.382	1.90	28.00
28	La Verne Irrigating Co.	Aug. 18	12	285	White & Middleton	35	212	do	5	Compound vertical	920	216	.481	27	95	122	6.65	3.75	.07	.262	.564	1,371	.14	17.50	3,100	.068	.039	.023	.130	.054	.179	6.10	22.00
29	White & Frisbee	Aug. 24	7	273	do	18	175	do	5	Single vertical	590	590	1.314	28	17.7	45.7	6.80	2.25	.05½	.124	.331	500			1,300	.076	.018		.094	.025	.129	1.10	5.90
30	Miller, N. W.	Sept. 12	10	245	do	23	212	do	5	do	665	437	.974	26.6	42	68.6	7.57	1.76	.05½	.097	.232	330			2,000	.160	.013		.173	.018	.238	1.20	16.00
31	Bowler & McCrosky	Aug. 10	10	400	Fairbanks-Morse	25	199	do	5	do	732	635	1.415	15	32.7	47.7	7.65	2.61	.05¼	.137	.341	1,694			2,300	.036	.018		.054	.025	.074	1.20	3.50
32	Townsend & Leslie	Sept. 9	10	450	White & Middleton	30	188	do	5	do	830	399	.889	27	53	80	8.06	2.50	.05¼	.131	.310	1,080	.10		3,500	.080	.016	.012	.108	.022	.148	1.80	12.00
33	Black & Cannon	Aug. 17	10	718	do	24	214	do	5	do	783	531	1.184	27.7	33	60.7	8.13	2.50	.05¼	.131	.308	2,100			3,036	.036	.016		.052	.022	.072	1.30	4.40
34	Fryer, Jas., and others	July 11	10	193	Otto	21	231	do	5	do	595	570	1.270	22	35	57	8.20	1.88	.05¼	.099	.229				1,893		.012			.016		.91	
35	Matthews, M. A.	Aug. 10	10	250	White & Middleton	30	190	do	5	do	787	472	1.052	23	49	72	8.58	2.03	.05¼	.107	.237	1,440	.15		1,800	.029	.012	.017	.058	.016	.080	1.20	5.80
36	Kingsley Tract Water Co.	June 1	7	250	Fairbanks-Morse	32	192	do	4	Compound vertical	900	371	.827	8	88	96	8.99	2.95	.06	.177	.328	496	.16⅔	1.40	3,200	.144	.020	.019	.183	.028	.252	2.70	24.00
37	Columbia Land and Water Co.	Aug. 15	12	140	Western	64	230	Krogh	5	do	685	398	.887	5	91	96	9.65	5.30	.06¾	.358	.549	1,560					.037			.051		4.90	
38	Himrod, T. B.	Aug. 11	10	308	Fairbanks-Morse	25	198	Byron Jackson	6	Single vertical	708	553	1.232	28.8	41.6	70.4	9.82	2.65	.05½	.146	.270	1,250			2,295	.037	.015		.052	.021	.072	1.50	5.10
39	Whipp, B. F.	Aug. 8	10	280	White & Middleton	32	170	do	5	do	685	568	1.265	24	45	69	9.89	2.25	.05½	.124	.228						.013			.018		1.20	
40	Armstrong, A.	Aug. 9	10	412	Western	30	206	do	5	Compound vertical	710	392	.873	22	83.5	105.5	10.43	4.25	.05¼	.223	.408	1,300			3,000	.044	.021		.065	.029	.089	3.10	9.40
41	Mosher, S. J.	June 8	10	500	West Coast	30	260	do	6	Single vertical	770	608	1.354	18	50	68	10.43	3.81	.05½	.210	.365	470		2.72	3,343	.136	.020	.001	.157	.028	.216	1.90	15.00
42	Frostless Belt Water Co.	July 18	12	255	White & Middleton	30	220	do	5	Compound vertical	740	303	.675	17.5	120	137.5	10.51	3.70			.352	2,800											
43	Vejar, R. J.	July 12	12	400	do	35	195	do	5	do	728	369	.822	25	88	113	10.52	4.15	.05½	.228	.394				3,100		.022			.030		3.40	
44	Thurman, R. M.	Sept. 27	10	385	do	30	203	Hunsaker	4	Single vertical	872	680	1.515	21	41	62	10.64	2.47	.06¾	.167	.232	850			2,500	.055	.016		.071	.022	.098	1.40	6.10
45	Matthews, L. R.	June 3	10	250	do	30	180	Byron Jackson	5	Compound vertical	840	484	1.078	19.5	74	93.5	11.42	2.76	.05¼	.145	.242	1,800	.25		3,200	.031	.013	.022	.066	.018	.091	1.70	8.50
46	Armstrong, P. T.	Aug. 9	10	375	do	35	185	do	5	do	715	490	1.092	24	71	95	11.75	3.34	.05½	.184	.284	720		13.00	4,000	.095	.016	.002	.113	.022	.155	2.10	15.00
47	Phillips, Louis, estate	June 10			do	35	200	do	6	do	700	592	1.319	23	67.4	90.4	13.51	4.25	.05	.212	.315	1,000	.12½		3,000	.044	.016	.009	.069	.022	.095	2.00	8.60

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Cost of pumping with gasoline engines and deep-well pumps, Pomona, 1905.

No.	Owner.	Date.	Well. Diameter.	Well. Depth.	Engine. Make.	Engine. Horsepower.	Engine. Revolutions per minute.	Pump. Make.	Pump. Acting.	Pump. Size of cylinder.	Pump. Stroke.	Pump. Strokes per minute.	Discharge—Per minute.	Discharge—Per second.	Lift.
			Inches.	*Feet.*									*Gallons.*	*Cubic ft.*	*Feet.*
65	Baker, E.	Oct. 8	7	130	Stearns	2	231	Stearns	Single	3½	9	37	13	0.029	20
66	Romine, W. F.	Aug. 22	7	145	do.	2	284	do.	do.	3½	9	48	20	.045	20
67	Mart, J. A.	Sept. 13	7	126	Root & Van Dervoort	2	278	Root & Van Dervoort	do.	4	7	39	14	.031	52
68	New Deal Land and Water Co.	July 27	12	385	Western	12	255	Pomona	Double	9	26	14	20	.045	84
69	Steel, B. E.	July 8	10	276	Root & Van Dervoort	3½	259		Single	....	10	29	21	.047	124
70	Harrison, F. E.	Sept. 16	10	97	White & Middleton	5	258	Addison	do.	7	18	28	83	.185	42
71	Jenks, Geo.	Aug. 21	10	175	Root & Van Dervoort	5	320	Gregory	do.	5	18	31	26	.058	160
72	Hickman, F. A.	Sept. 16	8	196	Perkins	8	202	Woodard	Double	6	21	18½	31	.069	165
73	Hays & Stratton	Aug. 25	7	175	Otto	12	170	do.	do.	5	30	24	46	.102	160
74	Callendar Bros.	Aug. 18	10	233	Hercules	25	152	Perkins	do.	7	24	18	52	.116	180
75	Firth, E.	Oct. 14	10	170	Fairbanks-Morse	12	210	Ames	do.	8	16	25½	94	.209	115
76	Sternberg, Jay	July 29	10	308	Lambert	15	140	Pomona	do.	5	16	26	50	.111	220
77	Worden, J. H.	Sept. 13	10	....	White & Middleton	10	180	Ames	do.	....	16	22	85	.189	138
78	Wood Bros.	July 28	10	300	do.	14	180	do.	do.	6	18	24½	76	.169	160
79	Sumner, C. B.	July 25	12	238	Witte	20	183	do.	do.	10	24	22	207	.461	65
80	Barthell Bros.	July 22	10	200	Fairbanks-Morse	12	220	do.	do.	7	19	30	94	.209	145
81	Curry & Elder	July 28	8	205	Lambert	12	190	do.	do.	6½	16	24	99	.221	140
82	Hart-Blake Co.	July 26	12	300	Fairbanks-Morse	12	200	Fairbanks-Morse	Single	8	24	24	114	.254	140
83	Teague, D. C.	July 31	12	260	Foos	12	200	Ames	Double	7	16	23	113	.252	150
84	Kelsey, D. R.	Aug. 4	10	161	White & Middleton	14	265	Means	do.	7	24	24½	183	.408	110
85	Baldridge, M.	Aug. 23	10	265	do.	14	218	Ames	do.	6	18	32	74	.165	278
86	Towne, Allen	July 22	12	320	Fairbanks-Morse	22	177	Fairbanks-Morse	Single	8	36	22	147	.327	145
87	Martin Bros.	Aug. 30	12	367	do.	25	186	Addison	Double	7	24	22½	108	.241	203
88	Olmstead, F. W.	Sept. 22	10	320	White & Middleton	23	187	Ames	do.	7	24	24	143	.319	190
89	Williams Bros.	July 26	12	375	Fairbanks-Morse	34	134	Williams	do.	9	36	15	213	.474	134
90	City of Pomona	May 27	10	65	do.	15	250	Pomona	do.	7	27	21	159	.354	180
91	Orange G. T. W. Co. and Packard Water Co.	Aug. 23	14	320	Stearns	25	206	do.	do.	10	32	21½	379	.844	83
92	Rutherford & Johnstone	July 26	12	217	Otto	30	160	Means	do.	9	24	20	144	.321	221
93	Meredith, L. C.	Aug. 25	10	265	White & Middleton	14	263	Addison	do.	9	24	24	298	.552	135
94	Schisler, H. R.	July 28	10	250	Fairbanks-Morse	14	146	Ames	do.	7	24	24	144	.321	235
95	Pitzer, L. C.	July 25	14	420	White & Middleton	30	198	Pomona	do.	9	36	17	275	.613	125
96	Herwig Bros.	July 18	12	375	Fairbanks-Morse	20	222	do.	do.	7	28	22	156	.348	225
97	Claremont Cooperative Water Co.	Aug. 21	12	277	Lambert	25	152	Ames	do.	9	24	22	241	.537	150
98	Citrus Water Co.	July 18	12	332	Columbus	35	152	Whitmer	do.	9	24	23	189	.421	197
99	Citrus Light and Power Co.	July 22	12	....	Western	30	273	Pomona	do.	10	36	15	257	.572	166
100	Baker, A. & Son	July 27	12	450	Fairbanks-Morse	34	180	do.	do.	9	30	21	224	.499	210
101	Thacker, L. S.	July 19	12	240	Hercules	30	165	do.	do.	9	36	17	258	.575	195
102	Swerdferger, A.	Sept. 22	12	300	Foos	50	140	Whitmer	do.	9	30	18	249	.555	205
103	Johnstone, J. A.	July 26	14	337	do.	26	154	Pomona	do.	9	28	23½	385	.858	140
104	Sparks, M. L.	July 27	12	324	White & Middleton	35	212	Ames	do.	9	30	23	252	.561	215
105	La Verne Land and Water Co.	July 28	12	340	Otto	38	200	do.	do.	8	24	27	385	.858	175

No.	Useful water horsepower.	Gasoline. Consumed per hour.	Gasoline. Cost per gallon.	Gasoline. Cost per hour.	Gasoline. Per useful water horsepower hour.	Total hours run in 1905.	Cost of attendance per hour.	Cost of repairs, 1905.	Total cost of plant.	Cost per useful water horsepower hour. Fixed charges.	Cost per useful water horsepower hour. Gasoline.	Cost per useful water horsepower hour. Attendance and repair.	Cost per useful water horsepower hour. Total.	Cost per foot-acre-foot. Gasoline.	Cost per foot-acre-foot. Total.	Cost per acre-foot of water pumped. Gasoline.	Cost per acre-foot of water pumped. Total.
		Gallons.			*Gallons.*												
65	0.0656	0.23	$0.07	$0.016	3.50	365	....	....	$500	$4.18	$0.244	....	$4.42	$0.335	$6.080	$6.70	$120.00
66	.101	.18	.17	.031	1.782	60	....	....	500	16.50	.307	....	16.81	.022	23.10	8.40	400.00
67	.184	.18	.07	.013	.978	500	....	....	500	1.09	.071	....	1.16	.098	1.10	5.10	83.00
68	.424	2.04	.07	.143	4.81	2,300	$0.12½	....	2,350	.481	.337	$0.295	1.11	.463	1.53	39.00	130.00
69	.657	.24	.07	.017	.365	1,560	....	....	....	....	.026	....	....	.036	....	4.50	....
70	.880	.54	.05½	.030	.614	320	....	....	700	.497	.034	....	.531	.047	.730	2.00	31.00
71	1.05	.42	.05¼	.022	.400	768	....	....	900	.223	.021	....	.244	.029	.335	4.60	54.00
72	1.29	1.40	.07	.098	1.085	160	....	....	1,500	1.45	.076	....	1.53	.109	2.10	17.00	350.00
73	1.86	1.15	.07	.080	.618	1,200	....	....	1,200	.108	.043	....	.151	.059	.208	9.40	33.00
74	2.36	1.35	.07	.094	.575	360	....	....	1,500	.353	.040	....	.393	.055	.540	9.90	97.00
75	2.73	1.28	.05½	.070	.469	48	....	....	....	....	.026	....	....	.036	....	4.10	....
76	2.78	.82	.05¼	.043	.295	1,920	....	$10.00	2,500	.094	.015	.002	.111	.021	.153	4.60	34.00
77	2.96	.97	.06¾	.065	.328	....	....	....	....	....	.022	....	....	.030	....	4.10	....
78	3.07	.80	.06	.048	.261	800	....	....	2,000	.163	.016	....	.179	.022	.246	3.50	30.00
79	3.40	2.60	.05½	.143	.765	744	....	....	2,650	.209	.042	....	.251	.058	.345	3.80	22.00
80	3.44	1.35	.05½	.074	.392	216	....	....	1,625	.456	.022	....	.478	.030	.657	4.40	95.00
81	3.50	1.52	.07	.106	.434	600	....	....	1,500	.143	.030	....	.173	.041	.238	5.70	33.00
82	4.03	.86	.07	.060	.213	2,530	....	25.00	2,200	.043	.015	.002	.060	.021	.082	2.90	11.00
83	4.28	2.20	.07	.154	.514	78	....	....	....	....	.036	....	....	.050	....	7.50	....
84	5.08	1.63	.05¼	.086	.321	....	....	12.00	2,100	....	.017	....	....	.023	....	2.50	....
85	5.19	1.02	.07	.081	.197	162	....	....	3,500	.832	.016	....	.848	.022	1.166	6.10	320.00
86	5.38	1.53	.05½	.084	.284	440	....	10.00	3,000	.253	.016	.004	.273	.022	.375	3.20	54.00
87	5.53	1.63	.05½	.090	.295	720	....	....	3,000	.151	.016	....	.167	.022	.230	4.50	47.00
88	6.86	2.16	....	....	.315	780	....	....	3,200	.120	....	....	....	....	....	....	....
89	7.20	2.10	.07	.147	.292	500	....	....	5,062	.281	.020	....	.301	.028	.414	3.80	55.00
90	7.22	1.64	.06	.098	.227	360	.20	....	1,555	.120	.014	.028	.162	.019	.223	3.40	40.00
91	7.94	3.06	.06¼	.191	.385	....	....	....	4,862	....	.024	....	....	.033	....	2.70	....
92	8.03	2.27	.06¾	.153	.283	....	....	....	....	....	.019	....	....	.026	....	5.70	....
93	8.45	1.56	.06¾	.105	.185	2,700	.15	....	2,300	.020	.012	.018	.050	.016	.069	2.20	9.30
94	8.54	2.11	.05½	.116	.247	1,440	.15	....	6,000	.098	.014	.018	.130	.019	.179	4.50	42.00
95	8.68	2.91	.05¼	.153	.335	2,279	.15	50.00	4,690	.047	.018	.020	.085	.025	.117	3.10	15.00
96	8.86	1.84	....	....	.208	....	....	....	....	....	....	....	....	....	....	....	....
97	9.12	2.45	....	....	.269	988	....	....	....	....	....	....	....	....	....	....	....
98	9.40	2.30	.06¾	.155	.245	2,088	.20	35.00	3,500	.036	.016	.023	.075	.022	.103	4.30	20.00
99	10.87	2.25	....	....	.207	....	....	....	....	....	....	....	....	....	....	....	....
100	11.9	3.90	.07	.273	.328	960	.20	....	2,000	.051	.023	.017	.091	.032	.125	6.70	26.00
101	12.7	3.45	.07	.242	.272	593	....	....	3,000	.078	.019	....	.097	.026	.133	5.10	26.00
102	12.9	2.59	.06¾	.175	.201	288	....	75.00	5,000	.267	.014	.020	.301	.019	.414	3.40	85.00
103	13.6	2.66	.06¾	.180	.196	1,680	.18	100.00	5,000	.044	.013	.018	.075	.018	.103	2.50	14.00
104	13.7	2.70	.07	.189	.197	1,100	.17½	30.00	8,000	.106	.014	.015	.135	.019	.186	4.10	40.00
105	17.0	3.45	.05½	.190	.203	....	....	....	....	....	.011	....	....	.015	....	2.60	....

ntrifugal pumps, Pomoña, 1905.

Lift.			Useful water horse-power.	Kilowa[tt] … r.	Cost per foot-acre-foot.		Cost per acre-foot of water pumped.	
Suction.	Discharge.	Total.			Electricity.	Total.	Electricity.	Total.
Feet.	*Feet.*	*Feet.*						
20.6	41.4	62	5.01	3	$0.069	$0.087	$4.30	$5.40
5	75	80	5.45	0	.076	.454	6.10	36.00
2	64	66	5.70	1..	.062	....	4.10	....
20	75	95	6.02	1..	.082	....	7.80	....
....	66	66	6.60	1..	.072	....	4.80	....
26.5	98	124.5	6.79	6	.085	.146	11.00	18.00
21	50	71	6.93	1..	.073	....	5.20	....
16	114	130	7.09	7	.058	.285	7.50	37.00
28.5	80	108.5	7.80	1..	.095	....	10.00	....
13.7	59.5	73.2	8.27	1..	.054	....	4.00	....
....	60.3	60.3	8.58	5	.066	.117	4.00	7.10
....	94.3	94.3	14.80	..	.052	....	4.90	....
25.1	97.3	122.4	15.3	4	.054	.157	6.00	19.00
23.5	196	219.5	16.6	..	.110	....	24.00	....
8	201	209	22.5	..	.078	....	16.00	....
....	194.5	194.5	31.1	..	.055	....	11.00	....
....	189	189	39	2	.047	.072	8.90	14.00

centrifugal pumps, Pomona, 1905.

…r …nd.	Lift.			Useful water horse-power.	…power	Cost per foot-acre-foot.		Cost per acre-foot of water pumped.	
	Suction.	Discharge.	Total.		Co… pe… Total.	Fuel oil.	Total.	Fuel oil.	Total.
ft.	*Feet.*	*Feet.*	*Feet.*		G…				
36	26.7	32.5	59.2	9.13	......	$0.030	....	$1.80	....
.577	32	132	164	10.7	......	.062	....	10.00	....
71	17.8	195.6	213.4	41.2	0.035	.022	$0.048	4.70	$10.00

Cost of pumping with electricity and centrifugal pumps, Pomona, 1905.

No.	Owner.	Date.	Well: Diameter.	Well: Depth.	Motor: Make.	Motor: Horsepower.	Motor: Revolutions per minute.	Pump: Make.	Pump: No.	Pump: Revolutions per minute.	Pump: Kind.	Discharge— Per minute.	Discharge— Per second.	Lift: Suction.	Lift: Discharge.	Lift: Total.
			Inches.	*Feet.*								*Gallons.*	*Cu. ft.*	*Feet.*	*Feet.*	*Feet.*
48	Sun Lee Co.	Sept. 26	10	200	General Electric	15	995	Byron Jackson	4	991	Single vertical	320	0.714	20.6	41.4	62
49	Henry, J. J.	Oct. —	10	220	do	20		do	4		do	270	.601	5	75	80
50	China Land and Water Co.	July 13	10	500	Westinghouse	20	768	do	5	768	do	342	.762	2	64	66
51	Wright Bros.	July 20	10	300	General Electric	15	900	do	4	1,245	do	251	.559	20	75	95
52	Consolidated Water Co. of Pomona	July 13			do	20	750	do	5	795	do	396	.882		66	66
53	Fulton, J. W.	July 10	10	225	do	20	745	do	3½	978	Compound vertical	216	.481	26.5	98	124.5
54	Palomares Irrigation Co.	July 13			do	20	748	do	5	655	Single vertical	387	.862	21	50	71
55	Brundige, C. N.	July 14	12	209	do	30	760	do	3	1,330	Compound vertical	216	.481	16	114	130
56	Kelsar Bros.	do			do	30	750	do	5	745	do	285	.635	28.5	80	108.5
57	Orange Grove Avenue Water Association	July 23	10	340	do	20	750	do	5	795	Single vertical	448	.998	13.7	59.5	73.2
58	Pomona Land and Water Co.	May 23		350	do	30	745	do	5	656	do	564	1.26		60.3	60.3
59	San Dimas Irrigation Co.	Aug. 5	12	200	do	40	758	do	5	713	Compound vertical	622	1.39		94.3	94.3
60	Currier Tract Water Co.	June 7	10	356	do	30	725	do	5	725	do	494	1.10	25.1	97.3	122.4
61	Western Water and Power Co.	Aug. 19	12	538	Westinghouse	75	600	do	5	747	do	299	.666	23.5	196	219.5
62	Glendora and Azusa Water Co.	June 13	12	531	do	100	580	do	6	790	do	427	.951	8	201	209
63	San Dimas Irrigating Co.	July 18	14	512	do	75	585	do	5	965	do	634	1.41		194.5	194.5
64	Glendora and Azusa Water Co.	June 13	12	531	do	100	580	do	6	790	do	818	1.82		189	189

No.	Useful water horsepower.	Electricity: Kilowatts.	Electricity: Cost per kilowatt.	Electricity: Cost per hour.	Electricity: Per useful water horsepower.	Total hours run in 1905.	Cost of attendance per hour.	Cost of repairs, 1905.	Total cost of plant.	Cost per useful water horsepower hour: Fixed charges.	Cost per useful water horsepower hour: Electricity.	Cost per useful water horsepower hour: Attendance and repairs.	Cost per useful water horsepower hour: Total.	Cost per foot acre-foot: Electricity.	Cost per foot acre-foot: Total.	Cost per acre-foot of water pumped: Electricity.	Cost per acre-foot of water pumped: Total.
					Kilowatts.												
48	5.01	10.9	$0.02½	$0.254	2.16	2,600			$1,150	$0.013	$0.050		$0.063	$0.069	$0.087	$4.30	$5.40
49	5.45	9.9	.03	.297	1.82	160			1,000	.275	.055		.331	.076	.454	6.10	36.00
50	5.70	12.7	.02	.254	2.23	2,700	$0.03				.045	$0.005		.062		4.10	
51	6.02	14.4	.02¼	.360	2.39	394					.060			.082		7.80	
52	6.60	17.3	.02	.346	2.62		.03				.052			.072		4.80	
53	6.79	18.8	.02¼	.423	2.77	600			1,200	.044	.062		.106	.085	.140	11.00	18.00
54	6.93	14.6	.02¼	.365	2.11		.03				.053			.073		5.20	
55	7.09	12.9	.02¼	.301	1.82	540		$30.00	4,000	.157	.042	.008	.207	.058	.285	7.50	37.00
56	7.80	23	.02¼	.537	2.95						.069			.095		10.00	
57	8.27	13	.02¼	.325	1.57				2,200		.039			.054		4.00	
58	8.58	16.4	.02¼	.410	1.91	1,440	.12	50.00	1,600	.019	.048	.018	.085	.066	.117	4.00	7.10
59	14.80	23.8	.02¼	.555	1.61						.038			.052		4.10	
60	15.3	23.6	.02¼	.590	1.54	558	.15	48.40	3,400	.050	.039	.015	.111	.054	.167	6.40	19.00
61	16.6	53	.02¼	1.325	3.19		.10				.080	.006		.110		24.00	
62	22.5	51.2	.02¼	1.280	2.28	900	.10	200.00			.057	.014		.078		16.00	
63	31.1	53.8	.02¼	1.255	1.73						.040			.055		11.00	
64	39	53.1	.02¼	1.328	1.36	3,000	.40		6,000	.008	.034	.010	.052	.047	.072	8.90	14.00

Cost of pumping with steam engines and centrifugal pumps, Pomona, 1905.

No.	Owner.	Date.	Well: Diameter.	Well: Depth.	Engine: Make.	Engine: Kind.	Engine: Horsepower.	Engine: Revolutions per minute.	Pump: Number.	Pump: Make.	Pump: Kind.	Pump: Revolutions per minute.	Discharge: Per minute.	Discharge: Per second.	Lift: Suction.	Lift: Discharge.	Lift: Total.
			Inches.	*Feet.*									*Gallons.*	*Cu. ft.*	*Feet.*	*Feet.*	*Feet.*
119	Larbeer, D. W.	Aug. 12	10	973	Atlas	Automatic; simple, noncondensing.	35	175	6	Byron Jackson	Single vertical	683	611	1.36	26.7	32.5	59.2
120	Artesian Belt Water Co.	July 21	12	380	do	do	75	192	5	do	Compound vertical	1,004	259	.577	32	132	164
121	Western Water and Power Co.	June 14	12	538	Risdon	Corliss; simple, noncondensing.	75	118	6	do	do	800	766	1.71	17.8	195.6	213.4

No.	Useful water horsepower.	Fuel oil: Consumed per hour.	Fuel oil: Cost per gallon.	Fuel oil: Cost per hour.	Fuel oil: Per useful water horsepower hour.	Total hours run in 1905.	Cost of attendance per hour.	Cost of repairs 1905.	Total cost of plant.	Cost per useful water horsepower hour: Fixed charges.	Cost per useful water horsepower hour: Fuel oil.	Cost per useful water horsepower hour: Attendance and repairs.	Cost per useful water horsepower hour: Total.	Cost per foot-acre-foot: Fuel oil.	Cost per foot-acre-foot: Total.	Cost per acre-foot of water pumped: Fuel oil.	Cost per acre-foot of water pumped: Total.
		Gallons.			*Gallons.*												
119	9.13	17.0	$0.0119	$0.202	1.86		$0.18				$0.022	$0.020		$0.030		$1.80	
120	10.7	27.3	.0178	.486	2.55						.045			.062		10.00	
121	41.2	33.7	.0192	.647	.818	4,320	.38		$10,000	$0.010	.016	.009	$0.035	.022	$0.048	4.70	$10.00

leep-well pumps, Pomona, 1905.

okes min- te.	Discharge. Per minute.	Discharge. Per second.	Lift.	Useful water horse-power.	r tal.	Cost per foot-acre-foot. Electricity.	Cost per foot-acre-foot. Total.	Cost per acre-foot of water pumped. Electricity.	Cost per acre-foot of water pumped. Total.
	Gallons.	*Cu. ft.*	*Feet.*						
27	184	0.410	65	3.02	...	$0.065	....	$4.20	....
22	194	.432	63	3.08	.82	0.070	$0.250	4.40	$16.00
23	336	.748	63	5.34	24	.063	.171	4.00	11.00
22½	135	.301	250	8.52	...	....	....	....	....
29	189	.421	197	9.40	...	.034	....	6.70	....
24	260	.579	145	9.51	...	.047	....	6.80	....
23	259	.577	150	9.80	...	.045	....	6.80	....
26	274	.610	150	10.4	...	.048	....	7.20	....
28	240	.535	175	10.6	91	.045	.125	7.90	22.00
23	421	.938	116	12.3	...	.038	....	4.40	....
21	270	.602	222	15.1	...	.033	....	7.30	....
22	334	.744	197	16.6	...	.036	....	7.10	....
20	267	.595	305	20.5	...	....	....	....	....

lifts, Pomona, 1905.

Discharge. Per minute.	Discharge. Per second.	Lift.	Useful water horse-power.	ver tal.	Cost per foot-acre-foot. Fuel oil.	Cost per foot-acre-foot. Total.	Cost per acre-foot of water pumped. Fuel oil.	Cost per acre-foot of water pumped. Total.
Gallons.	*Cu. ft.*	*Feet.*						
208	0.463	65	3.41	....	$0.026	....	$1.70	....
134	.298	124	4.19	460	.070	$0.632	8.70	$78.00
600	1.34	50	7.57	100	.066	.138	3.30	6.90
635	1.41	93	14.9	....	....	....	....	....
478	1.06	159	19.2	....	....	....	....	....
952	2.12	88	21.1	062	.032	.085	2.80	7.50
2,078	4.63	42	22.0	091	.030	.125	1.30	5.20
1,056	2.35	106	28.2	....	....	....	....	....

Cost of pumping with electricity and deep-well pumps, Pomona, 1905.

No.	Owner.	Date.	Well.		Motor.			Pump.					Discharge.		Lift.	Useful water horse-power.	Electricity.				Total hours run in 1905.	Cost of attendance per hour.	Cost of repairs, 1905.	Total cost of plant.	Cost per useful water horsepower hour.				Cost per foot-acre-foot.		Cost per acre-foot of water pumped.	
			Size.	Depth.	Make.	Horse-power.	Revolutions per minute.	Make.	Acting.	Size of cylinder.	Stroke.	Strokes per minute.	Per minute.	Per second.			Kilowatts.	Cost per kilowatt.	Cost per hour.	Per useful waterhorse-power.					Fixed charges.	Electricity.	Attendance and repairs.	Total.	Electricity.	Total.	Electricity.	Total.
			Inches.	*Feet.*									*Gallons.*	*Cu. ft.*	*Feet.*					*Kilowatts.*												
106	Consolidated Water Co. of Pomona	July 13			General Electric	10	995	Addison	Double	7	24	27	184	0.410	65	3.02	5.7	$0.02½	$0.142	1.89		$0.07				$0.047			$0.105		$4.20	
107	do	June 16			do	10	750	do	do	7	24	22	194	.432	63	3.08	6.3	.02½	.158	2.05	2,160	.07	$180	$3,580	$0.081	.051	$0.050	$0.182	0.070	$0.250	4.40	$16.00
108	do	May 24			do	20	745	do	do	10	24	23	336	.748	63	5.34	9.8	.02½	.245	1.84	2,160	.07	10	4,950	.064	.046	.014	.124	.043	.171	4.00	11.00
109	Green & Pitzer	July 31	10	340	do	20	735	Means	do	7	23	22½	135	.301	250	8.52	13.1			1.54			15	4,000								
110	Gross, S. L.	July 14	9		do	15	1,004	do	do	7	18	29	189	.421	197	9.40	9.9	.02½	.231	1.05						.025			.034		6.70	
111	Pomona Ranch Water Co.	Oct. 20	12	285	do	20	750	Pomona	do	10	28	24	260	.579	145	9.51	16.0	.02	.320	1.68						.034			.047		6.80	
112	do	do	12	275	do	20	750	do	do	10	28	23	259	.577	150	9.80	16.0	.02	.320	1.63						.033			.045		6.80	
113	Lordsburg Water Co.	July 12	10	292	do	20	750	do	do	8	18	26	274	.610	150	10.4	15.6	.02½	.364	1.50				2,500		.035			.048		7.20	
114	Mesa Land and Water Co.	July 23	12	300	do	30	750	Ames	do	8	24	28	240	.535	175	10.6	13.9	.02½	.348	1.31	1,669	.08	258	4,249	.036	.033	.022	.091	.045	.125	7.90	22.00
115	Del Monte Irrigation Co.	do	14	152	Westinghouse	15	980	Pomona	do	10		23	421	.938	116	12.3	14.9	.02½	.348	1.21	3,192	.07				.028			.038		4.40	
116	Crawford Bros.	July 29	10	225	General Electric	30	745	2 Ames	do	7	24	21	270	.602	222	15.1	18.0	.02	.360	1.19				6,000		.024			.033		7.30	
117	Gross, S. L.	July 14	12		do	30	750	Means	do	10	24	22	334	.744	197	16.6	18.5	.02½	.432	1.11						.026			.036		7.10	
118	Means, J. L.	Aug. 1	14	349	do	30	743	2 Means	do	7	24	20	267	.595	305	20.5	29.6			1.44												

Cost of pumping with air lifts, Pomona, 1905.

No.	Owner.	Date.	Well.			Compressor.						Discharge.		Lift.	Useful water horse-power.	Fuel oil.				Total hours run in 1905.	Cost of attendance per hour.	Cost of repairs 1905.	Total cost of plant.	Cost per useful water horsepower hour.				Cost per foot-acre-foot.		Cost per acre-foot of water pumped.	
			Number.	Size.	Depth.	Make.	Kind.	Horse-power.	Revolutions per minute.	Air cylinder.	Air pressure.	Per minute.	Per second.			Consumed per hour.	Cost per gallon.	Cost per hour.	Per useful water horsepower hour.					Fixed charges.	Fuel oil.	Attendance and repairs.	Total.	Fuel oil.	Total.	Fuel oil.	Total.
				Inches.	*Feet.*					*Inches.*	*Lbs. per sq. in.*	*Gallons.*	*Cu. ft.*	*Feet.*		*Gallons.*			*Gallons.*												
122	Campbell, M.	July 20	2	7	215	Smith-Vaile	Belted to Witte gas engine		107		50	208	0.463	65	3.41	1.19	$0.055	$0.065	0.349			$50	$2,500		$0.019			$0.026		$1.70	
123	Fleming, M.	Aug. 18	1	7	250	do	Throttling simple condensing tandem	25	100	12×12	68	134	.298	124	4.19	11.2	.019	.213	2.67	360	$0.20		3,200	$0.361	.051	$0.048	$0.460	.070	$0.632	8.70	$78.00
124	San Dimas Irrigating Co.	June 17	3	7	175	Hall	Throttling simple noncondensing tandem	35	110	14×12	54	600	1.34	50	7.57	20.0	.018	.360	2.64	5,800	.25		5,000	.019	.048	.033	.100	.066	.138	3.30	6.90
125	Ontario Water Co.	Sept. 8	5	12		Smith-Vaile	Corliss compound condensing tandem	125	110	14×18	73	635	1.41	93	14.9	29.5			1.98	650											
126	Richards Ranch	July 20	2	10		do	do	125	89	14×18	105	478	1.06	159	19.2	26.5			1.38	1,740			6,000	.031							
127	Del Monte Irrigation Co.	June 15	7	10		do	do	125	105	16×18	57	952	2.12	88	21.1	26.7	.018	.481	1.27	3,840	.47	92	7,500	.016	.023	.023	.062	.032	.085	2.80	7.50
128	Irrigation Company of Pomona	June 6	15	7	361	Rand	do	200	73	17×24	58	2,078	4.63	42	22.0	27.0	.018	.486	1.23	5,000	.31½	25	35,000	.054	.022	.015	.091	.030	.125	1.30	5.20
129	Covina Irrigation Co.	Oct. 3	6	10	375	Hamilton	Corliss simple condensing tandem	125	68	18×36	70	1,056	2.35	106	28.2	33.9			1.20												

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The plants are classified according to the type of machinery used, and in each table the tests are arranged in order according to the amount of useful water horsepower developed during the test, beginning with the smallest plant. Forty-seven plants use gasoline engines and centrifugal pumps; 17 plants use electric motors and centrifugal pumps; 41 plants use gasoline engines and deep-well pumps; 13 plants use electric motors and deep-well pumps; 3 plants use steam engines and centrifugal pumps; and 7 plants use steam engines running air lifts. These include all the plants around Pomona upon which it was possible to secure the desired data

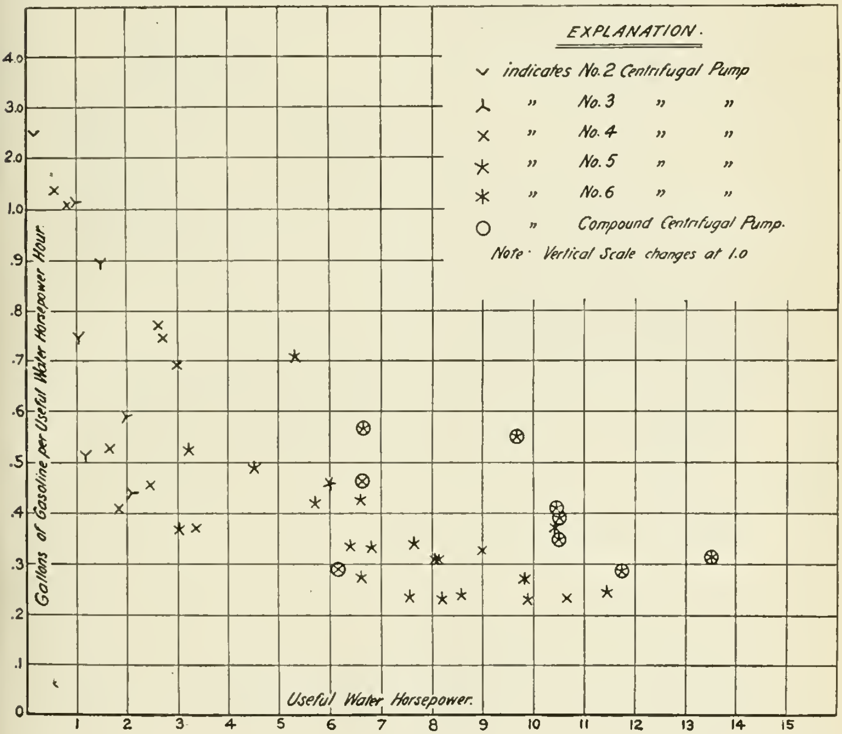

FIG. 6.—Diagram showing gasoline used per useful water horsepower hour with centrifugal pumps of different sizes.

regarding their operation, although in some cases the data are incomplete. In addition there were about 14 plants in operation which it was not feasible to test, about 17 not in operation on account of a sufficient supply of running water for irrigation, and about 15 plants which appeared to have been definitely abandoned, giving a total of about 175 pumping plants in the region studied.

In beginning the investigation at Pomona valuable assistance was rendered by the committee of the Pomona and Claremont Farmers' Clubs having under consideration a central power plant for pump-

ing. The members of the committee were J. E. Adamson, M. E. (chairman), H. J. Nichols, Walter A. Lewis, E. M. Wheeler, and George P. Robinson, C. E. The Edison Electric Company, by its manager, Mr. F. W. Balfour, extended many courtesies which aided in testing electrical plants. Others who rendered particular favors were Mr. William Bowering, Mr. E. P. Fiery, and Mr. N. C. Pedley. All owners of pumping plants very kindly allowed privileges and the machine and pump companies of Pomona gave information.

For the purpose of comparison the amount of gasoline used per useful water horsepower hour in the gasoline plants, the amount of electricity in the electrical plants, and the amount of fuel oil in the

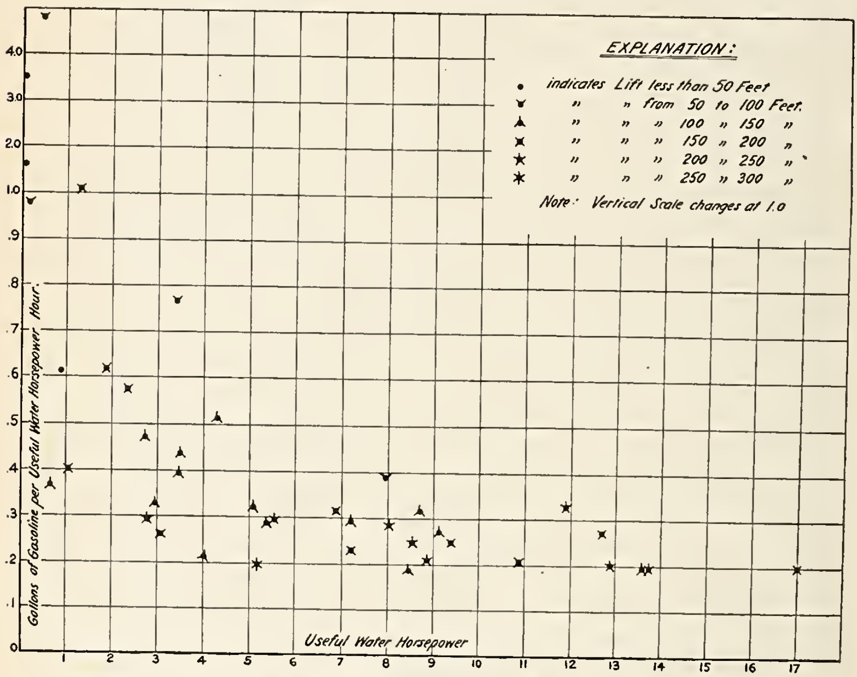

FIG. 7.—Diagram showing gasoline used per useful water horsepower hour with deep-well pumps of different sizes.

steam plants have been platted on the accompanying diagrams (figs. 6, 7, 8, 9). These show plainly that there is economy in fuel consumption in the larger plants as compared with the smaller ones, but the most striking fact is the great variation in fuel consumption in the different plants. In the gasoline plants the amount of gasoline consumed spreads over a range reaching as a maximum about double the quantity required for the most economical plants. This represents a waste of fuel which would be avoided if all the plants were properly designed and installed and maintained in fit condition for operation. The electrical and steam plants are so much less

numerous that the range of variation in economy is not so definitely indicated.

Omitting some of the smallest plants, but including all the others for which the necessary data are given, it appears that the amount

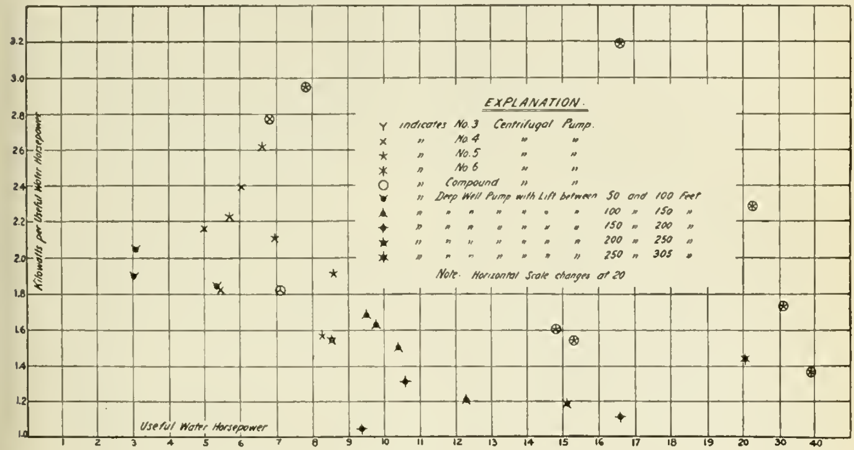

FIG. 8.—Diagram showing electrical power used per useful water horsepower with plants of different sizes.

of gasoline consumed by 40 gasoline-engine centrifugal-pump plants in 1905 was 90,000 gallons. If all the plants had been as economical as

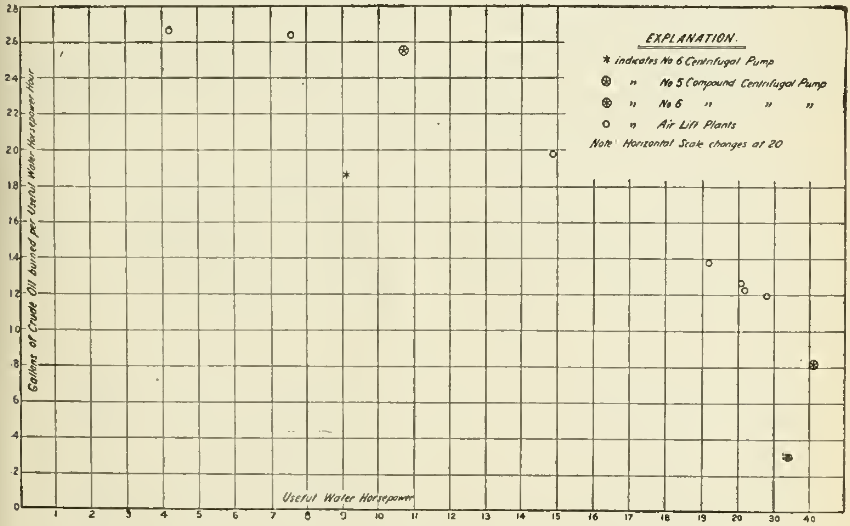

FIG. 9.—Diagram showing crude oil used per useful water horsepower hour with plants of different sizes.

the better ones tested, the amount of gasoline required would have been about 63,000 gallons, indicating a consumption of 27,000 gallons more than necessary. Similarly, 28 deep-well plants used 51,000 gallons of gasoline, while the most economical plants indicate that

40,000 gallons should have been sufficient. Hence, these 68 plants used 38,000 gallons of gasoline more than necessary. At 7 cents a gallon this was worth $2,660. At 12 cents a gallon, which is more nearly the average price elsewhere, the gasoline would have had a value of $4,560. Sixty-eight was just about half the number of plants in operation around Pomona, hence if the remainder, including the electrical and steam plants, had an economy as much below that possibly attainable, the total loss from excessive consumption of fuel is $5,000 to $10,000 a year. Furthermore, there would be an additional saving if there were fewer small plants and more large ones, such as might be obtained by more extensive cooperation in the installation of pumping plants.

The total cost of all the pumping plants in this district is approximately $500,000. Although no definite figures can be given, it seems probable that at least 25 per cent of this might have been saved by more knowledge of what was most suitable in the way of proper equipment for the plants that have been installed. Ignoring the question of loss through abandonment of unsuitable equipment, the interest on this unnecessary expenditure reaches a large figure.

MAINTENANCE OF PUMPING PLANTS.

Like all kinds of machinery, and perhaps more than many kinds, pumping machinery is subject to many injuries and requires constant attention to maintain it constantly in working order. Even with careful attention there will occasionally be serious and aggravating breakdowns. To illustrate the amount and nature of repairs and supplies necessary, the following records have been selected:

THE MESA LAND AND WATER COMPANY, POMONA.

A 30-horsepower induction motor; an 8 by 24 deep-well pump; one 12-inch well, 300 feet deep, supplying 240 gallons per minute, under 175 feet head. Total cost for repairs for 1904, $178.73.

Cost of repairs for 1905.

Valves and leathers	$77.17
Babbitt for motor box	4.20
Labor	14.25
Labor pulling rods	3.40
2 brass couplings	5.00
2-pound rubber gasket	.60
Forge work for pump	.50
Boring and threading nuts	1.70
Cup leathers	3.20
Repairing rods	12.00
Labor, removing broken gear	2.63
Telegram	1.00
Cut pinion	19.00

Gear	$22.50
Express on gears	2.00
Box cover	6.20
Machine work	2.80
Drayage on pump parts	2.00
Repairs crosshead and rods	2.70
Babbitt	3.15
Labor	6.00
Labor, drilling crosshead and threading rods	2.10
Forge work	.35
Shafting	.20
Three 8-inch couplings	2.70
Brass rod and couplings	15.00
Pipe and fitting same	9.80
Machine work	5.50
Labor	7.00
3 pounds hemp packing	.30
Brass coupling	3.00
Labor	3.00
Pipe and threading of same	.65
Labor	2.70
Brass couplings	9.00
Reducer	.20
Labor, pulling rods	4.20
Total	257.70

F. W. OLMSTEAD'S PLANT, NEAR POMONA.

A 23-horsepower gasoline engine; a 7 by 24 deep-well pump; one 10-inch well, 320 feet deep, discharging 143 gallons per minute, under 193 feet lift.

Cost of repairs and incidentals for 1902.

Apr.	Platform for distillate tank	$2.00
	Float for same	1.00
	Funnel	.25
	Labor on belt	1.00
June.	5 gallons cylinder oil	3.00
	1 cup leather	1.00
	Labor on plant	8.50
	Packing	.20
July.	Labor on belt, engine, and pump	1.95
	5 gallons engine oil	2.50
	Renewal of battery (4 cells)	7.20
	Labor on pump and belt	.95
Aug.	3 gallons cylinder oil	1.80
	1 pound belt filling	.40
	6 belt lacings	.75
	Labor on belt	.85
Sept.	One electrode	2.25
	Labor on engine	.75
Oct.	5-inch elbow	2.00
	11 feet of 5-inch pipe	7.70

Oct.	Threading pipe	$1.50
	Plug	.05
	One electrode	2.50
	5 feet of 4-inch pipe	3.73
	Labor on engine	1.25
Nov.	10 pounds waste	1.10
	Labor on engine	.30
	Total	56.48

Cost of repairs and incidentals for 1903.

Mar.	Repairs on cement floor	$4.00
May.	5 gallons cylinder oil	3.00
	Asbestos packing	.10
	5 gallons engine oil	2.50
	Labor at plant	2.50
	Cementing weir box	1.00
	1½ pounds belt dressing	.75
	Monkey wrench	.75
	"S" wrench	.35
	Rivets	.75
	Vise	9.00
	Pliers	.60
	Screwdriver	.30
	4½ feet belt	2.25
	Freight	.25
	Lumber for bench	.95
June.	Renewal of battery, 5 cells	8.75
	Labor on engine and battery	1.25
July.	Labor on engine and belt	.50
Aug.	Rivets	.35
	1 long electrode	2.75
	Labor on belt	.50
Sept.	Labor on engine, belt, and electrode	3.90
	5 gallons cylinder oil	3.00
Oct.	Wrench	.50
	Iron straps and bolts for belt	.72
	5 gallons engine oil	2.50
	Labor on pulley and belt	1.13
Nov.	5 gallons engine oil	2.50
	Renewing battery, 3 cells	4.80
	Labor on engine	1.70
Dec.	1 brass coupling for pump	.85
	Packing for pump	.65
	Turning escape valve	.80
	Asbestos packing	.25
	Oil can	.15
	1 can gasoline	1.15
	Renewing battery, 2 cells	3.20
	Labor on engine and in pulling rods on pump	11.50
	Total	82.75

Cost of repairs and incidentals for 1904.

Jan.	Labor on engine	$1.75
Feb.	Labor on engine	.25
May.	5 gallons cylinder oil	3.25
	Water connection for engine	2.50
	Insulated wire, binding screws, and brass	.60
	Tub and fitting	.90
	Plumbing	1.00
	Float	.20
	Distillate pump	3.00
	Glass for oil cup	.25
June.	2 cup leathers and labor	1.70
	5 gallons cylinder oil	3.00
	5 gallons engine oil	2.50
	Hauling rods and labor	9.00
	Machine work on pump	2.20
	3 leathers for valves (pump)	2.25
	2 couplings for pump	2.25
	13 pounds steel	.40
	4 brass couplings for pump	3.00
	Belt dressing	.45
	Waste	.25
	Labor at plant	10.20
Aug.	Renewal of battery	8.25
	5 gallons of cylinder oil	3.25
	Labor	.75
Sept.	5 gallons cylinder oil	3.00
	Labor on engine	.80
Oct.	5 gallons gasoline	.95
Nov.	Labor on engine and belt	1.75
Dec.	5 gallons cylinder oil	3.25
	2 pairs chain tongs, chain sling, and 3 clamps	8.00
	1 electrode	3.00
	Total	83.55

Cost of repairs and incidentals for 1905.

Jan.	Labor on engine (14 hours)	$2.45
May.	Waste	1.00
	New pin for engine eccentric	1.35
June.	Labor on engine	.44
	Belt dressing	.45
July.	Renewal of battery	8.00
	Repairs on exhaust valve	.50
	Repairs on distillate pump	.25
Aug.	5 gallons gasoline	.95
Sept.	Labor on belt	.15
	Distillate tank	10.00
	Freight on tank	.25
	10 gallons engine oil	4.50
	5 gallons cylinder oil	2.75

Sept.	Freight on oil	$0.50
Oct.	Faucet for distilling tank	.65
	Total	34.19

Average total for four years	64.24
Total first cost of the installation	$3,161.73
Total hours run in 1905	785½
Total gallons of gasoline used in 1905	1,588
Gallons used per hour	2.02

R. M. THURMAN'S PLANT, NEAR POMONA.

A 23-horsepower gasoline engine; a No. 5 single centrifugal pump; one 10-inch well, 385 feet deep, supplying 458 gallons per minute, under 58 feet head.

Expense of having well tested before installation of machinery.

Mar.	1.	Labor of 2 men, three-fourths day, for putting in pump	$4.00
	3.	Running pump one day	8.00
	12.	Oil, waste, and incidentals	9.40
	12.	Labor, 2 men, four hours, taking out pump	3.00
		Total	24.40

March 22. Total cost of engine and pump, entirely installed with belt and ready to run, $1,382. (This does not include well, pit, building, etc.)

Cost of repairs and incidentals for 1900.

Apr.	28.	Labor on engine	$1.00
May	3.	5 gallons machine oil	3.00
	29.	5 gallons cylinder oil	3.25
June	11.	4 hours labor, 1 man	1.50
July	11.	5 gallons cylinder oil	3.25
	20.	1½ feet 10-inch belt	.75
	20.	Belt laces	60
	28.	Difference in changing belt	10.00
	28.	Repairs on valves (engine)	.50
	28.	3 gallons machine oil	1.80
	31.	5 dozen belt hooks	.75
Aug.	8.	1 pound belt dressing	.50
	20.	Labor on pump	1.25
Sept.	3.	Valve for engine	2.75
	4.	4 belt laces, ⅝ inch	.75
Nov.	9.	Labor, 2 men, in taking out pump and replacing it	4.50
		Total	36.15

Cost of repairs and incidentals for 1901.

Apr.	11.	Asbestos paper	$0.20
	11.	Graphite	.15
	11.	Renewal of battery of 6 cells	6.90
May	23.	5 gallons cylinder oil	3.25
	23.	5 gallons machine oil	3.00
		Total	13.50

Cost of repairs and incidentals for 1902.

Jan.	6.	Labor, one-half day, 2 men repairing pump	$3.50
	20.	5 gallons cylinder oil	3.00
	20.	5 gallons machine oil	2.75
	20.	2 8 by 2 inch nipples	.50
	20.	2 2-inch elbows	.50
	20.	Labor, one man for three-fourths day	3.00
Mar.	11.	Labor one-fourth day	.75
Apr.	17.	1 pump	2.50
	17.	1 bushing	.15
July	7.	5 gallons cylinder oil	3.25
Aug.	7.	5 gallons machine oil	2.75
Sept.	10.	1 gallon cylinder oil	.65
		Total	23.30

During February, 1901, the pit and pump were lowered a distance of 20 feet for a total cost of $218.22.

Cost of repairs and incidentals for 1903.

May	24.	8 charges for Edison battery, type 2	$9.20
June	6.	Labor on battery	.63
	10.	5 gallons cylinder oil	3.25
	10.	5 gallons machine oil	2.75
	29.	5-inch check valve	12.50
	29.	Labor putting in check valve	1.50
	29.	No. 3 rubber gasket	.90
	29.	4 $\frac{5}{8}$ by $2\frac{1}{2}$ inch bolts	.20
	29.	12 by 16 inch iron pulley	9.75
	29.	Belt hooks	.40
	29.	Belt laces	.30
	29.	2 oil cans	.25
	29.	18 inches 10-inch 6-ply canvas belt	.90
July	2.	3 hours' labor, 2 men (on pump)	2.00
	2.	18 inches $\frac{3}{8}$-inch pipe	.10
	8.	Belt hooks	1.00
	11.	3 hours' labor, 1 man in packing pump	1.75
Aug.	10.	5 gallons machine oil:	2.75
	18.	Labor on sparker	.15
	20.	3 springs for sparker	.75
	24.	2 hours' labor on engine	.50
	28.	5 gallons cylinder oil	3.25
		Total	54.78

Cost of repairs and incidentals for 1904.

Mar.	11.	5 gallons machine oil	$2.75
May	12.	2 feet 6-ply 10-inch belt	1.20
	17.	1 gallon machine oil	.55
	24.	5 gallons cylinder oil	3.25
June	2.	5 gallons machine oil	2.75
	14.	1 box belt hooks	1.75
	27.	5 gallons cylinder oil	3.25

July	7.	5 gallons machine oil	$2.75
	9.	Asbestos paper	.40
Aug.	12.	5 gallons cylinder oil	3.25
	12.	5 gallons machine oil	2.75
		Total	24.65

In 1905 the 23-horsepower engine was replaced by one of 30 horsepower to suit the increasing head. Credit of $700 was allowed for the old engine and the difference paid for the new engine was $847.

The entire pump was overhauled and new cross timbers and cement work put in for $156. The total expense for 1905 was $32.30.

BRAKE HORSEPOWER TESTS.

Measurements of both brake and indicated horsepower were made on three plants. The Prony brake used on these occasions is shown in figure 10. A piece of ordinary canvas belting surrounds the fly

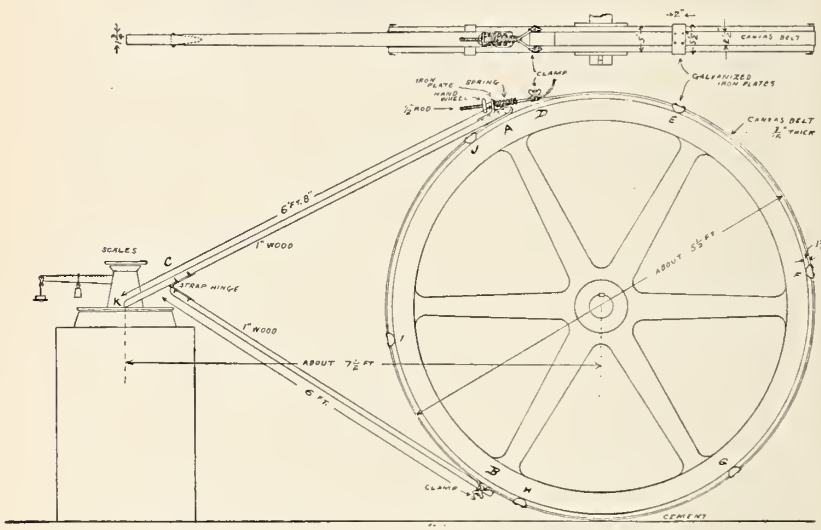

FIG. 10.—Dynamometer on gas engines.

wheel of the engine, and is fastened to two wooden strips at A and B. These in turn are fastened together at C by a strap hinge, so as to form a triangular frame. The free end of the belt at D is connected to an adjustable clamp, and this by a handwheel to the point A.

Cleats of galvanized iron at E, F, G, H, etc., prevent the belt from slipping off the rim of the wheel, and any desired tension can be obtained by the handwheel at A. The end of the wooden frame rests at K on a platform scale. This form of brake has the advantage of being adaptable to engines where the fly wheel very nearly touches the floor and also of being light and easily transported. By changing the position of the clamp D it can be made to fit fly wheels of different sizes.

Brake horsepower tests such as the following, made under the difficult conditions that arise in field work, can not be expected to give as accurate results as can be obtained in a perfectly equipped mechanical laboratory. The following results are fair for field tests:

BRAKE TEST NO. 1, PLANT OWNED BY THE SAM LEE COMPANY.

A Fairbanks-Morse gasoline engine, rated at 12-brake horsepower. Size of cylinder, $8\frac{5}{16}$ by 14 inches. Belt thrown off entirely. Indicator spring, No. 200. Length of dynamometer arm, 7.43 feet. Unbalanced weight, 3.5 pounds.

Brake test No. 1, Sam Lee Company, September 30, 1905.

No.	Time.	Revolutions per minute of engine.	Explosions per minute.	Area of card.	Length of card.	Mean effective pressure per square inch.	Indicated horsepower.	Weight on scales.	Brake horsepower.	Friction horsepower.	Per cent of loss in engine.
				Sq. in.	Inches.	Pounds.		Pounds.			
1	2.00......	285	79	0.95	2.37	80.2	12.2	23.5	8.1	4.1	33
2	2.05......	288	86	1.00	2.36	84.7	14.0	25.0	8.8	5.2	37
3	3.20......	286	121	.87	2.34	74.3	17.2	32.0	11.5	5.7	33
4	4.45......	270	130	.97	2.36	82.2	20.5	44.0	15.5	5.0	24

BRAKE TEST NO. 2, PLANT OWNED BY R. M. THURMAN.

A White & Middleton gasoline engine, rated at 30-brake horsepower. Size of cylinder, 10 by 18 inches. Belt thrown entirely off the engine. Indicator spring, No. 200. Length of dynamometer arm, 7.46 feet. Unbalanced weight, 3 pounds.

Brake test No. 3, R. M. Thurman, October 27, 1905.

No.	Time.	Revolutions per minute of engine.	Explosions per minute.	Area of card.	Length of card.	Mean effective pressure per square inch.	Indicated horsepower.	Weight on scales.	Brake horsepower.	Friction horsepower.	Loss in engine.
				Sq. in.	Inches.	Pounds.		Pounds.			Per ct.
1	1.35....	207	27	1.55	2.95	105.1	10.1	13	2.9	7.2	71
2	1.40....	207	31	1.56	2.95	105.8	11.7	23	5.9	5.8	50
3	1.45....	208	44	1.50	2.95	101.7	16.0	33	8.9	7.1	44
4	1.50....	207	51	1.50	2.95	101.7	18.5	43	11.8	6.7	36
5	1.55....	208	60	1.56	2.95	105.8	22.7	53	14.8	7.9	35
6	2.15....	207	65	1.56	2.90	107.6	25.0	63	18.5	6.5	26
7	2.20....	207	70	1.56	2.94	106.1	26.5	73	20.6	5.9	22
8	2.25....	207	83	1.52	2.93	103.8	30.8	83	23.5	7.3	24
9	2.30....	205	92	1.52	2.95	103.0	33.8	93	26.2	7.6	22
10	2.35....	193	97	1.42	2.90	97.9	33.9	103	27.4	6.5	19

BRAKE TEST NO. 3, PLANT OWNED BY MARTIN BROTHERS.

A Fairbanks-Morse gasoline engine, rated at 25-brake horsepower. Size of cylinder, $10\frac{1}{2}$ by 18 inches. Friction clutch thrown out and belt run on idler of pump. Indicator spring, No. 200. Length of dynamometer arm, 7.48 feet. Unbalanced weight, 3 pounds.

Brake test No. 2, Martin Brothers, October 25, 1905.

No.	Time.	Revolutions per minute of engine.	Explosions per minute.	Area of card.	Length of card.	Mean effective pressure per square inch.	Indicated horsepower.	Weight on scales.	Brake horsepower.	Friction horsepower.	Per cent of loss in engine.
				Sq. in.	*Inches.*	*Pounds.*		*Pounds.*			
1	1.35......	190	18	1.39	2.96	93.9	....	0	....	....	....
2	1.30......	189	18	1.40	2.96	94.6	....	0	....	....	....
	Average.	189.5	18.0	....	....	94.2	6.7	0.0	0.0	6.7	100.0
3	1.25......	188	34	1.35	2.95	91.5	....	18	....	....	....
4	1.20......	189	30	1.37	2.96	92.6	....	18	....	....	....
	Average.	188.5	32.0	....	....	92.0	11.6	18.0	4.0	7.6	66
5	1.15......	188	35	1.37	2.95	92.9	....	23	....	....	....
6	1.10......	188	34	1.37	2.96	92.6	....	23	....	....	....
	Average.	188.0	34.5	....	....	92.8	12.6	23.0	5.4	7.2	57
7	1.05......	188	38	1.30	2.94	88.4	....	28	....	....	....
8	1.00......	188	37	1.37	2.95	92.9	....	28	....	....	....
	Average.	188.0	37.5	....	....	90.6	13.4	28.0	6.7	6.7	50
9	12.55.....	187	43	1.30	2.94	88.4	....	33	....	....	....
10	12.50.....	188	43	1.35	2.95	91.5	....	33	....	....	....
	Average.	187.5	43.0	....	....	90.0	15.2	33.0	8.0	7.2	47
11	12.45.....	188	47	1.30	2.95	88.1	....	38	....	....	....
12	12.40.....	185	51	1.29	2.96	87.2	....	38	....	....	....
	Average.	186.5	49.0	....	....	87.6	16.9	38.0	9.3	7.6	45
13	12.35.....	182	50	1.30	2.93	88.7	....	43	....	....	....
14	12.30.....	186	51	1.33	2.95	90.2	....	43	....	....	....
	Average.	184.0	50.5	....	....	89.4	17.8	43.0	10.5	7.3	41
15	11.00.....	182	64	1.06	2.92	72.6	....	48	....	....	....
16	11.05.....	182	62	1.11	2.94	75.5	....	48	....	....	....
	Average.	182.0	63.0	....	....	74.0	18.4	48.0	11.7	6.7	36
17	11.10.....	180	66	1.10	2.94	74.8	....	53	....	....	....
18	11 15.....	182	66	1.10	2.93	75.1	....	53	....	....	....
	Average.	181.0	66.0	....	....	75.0	19.5	53.0	12.9	6.6	34
19	11.20.....	183	72	1.07	2.92	73.3	....	58	....	....	....
20	11.25.....	182	71	1.09	2.92	74.7	....	58	....	....	....
	Average.	182.5	71.5	....	....	74.0	20.8	58.0	14.3	6.5	31
21	11.30.....	181	77	1.07	2.93	73.0	....	63	....	....	....
22	11 35.....	181	76	1.09	2.93	74.4	....	63	....	....	....
	Average.	181.0	76.5	....	....	73.7	22.2	63.0	15.5	6.7	30
23	11.40.....	178	81	1.08	2.92	74.0	....	68	....	....	....
24	11.45.....	180	82	1.08	2.94	73.5	....	68	....	....	....
	Average.	179.0	81.5	....	....	73.8	23.7	68.0	16.6	7.1	30
25	11.50.....	172	75	1.00	2.94	68.0	....	73	....	....	....
26	11.55.....	174	77	1.00	2.93	68.3	....	73	....	....	....
	Average.	173.0	76.0	....	....	68.2	20.4	73.0	17.2	3.2	16

These three brake tests agree in showing that the power consumed in the friction of the gasoline engine itself is approximately constant for a given speed of the engine, no matter how much useful work the engine is doing. The results also indicate that the smaller the engine the larger is the proportion of the whole power developed by the engine that is consumed in overcoming the friction of the engine itself. When the engines were running to their full capacity with an explosion every second revolution the amount of power consumed in the friction of the engine was 20 to 30 per cent of the whole power developed, and as the loads on the engine were reduced the friction horsepower became a correspondingly greater fraction of the total indicated horsepower.

These tests show conclusively the uneconomical results that come from using a gasoline engine too large for the work it is to do. In such a case every time the engine misses an explosion a certain amount of work is wasted in carrying the engine through the useless revolutions. Hence, in general, a gasoline engine works to the greatest advantage when the explosions take place regularly and as often as possible.

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